Table 16. OCCURRENCE OF SELECTED PATHOGENIC BACTERIA IN BACKGROUND SAMPLES, PERCENT

Sample site	*Salmonella* sp.	*P. aeruginosa*	*Staph. aureus*
A Raw sewage	100	100	93
B Herring Run	84	100	57
C Jones Falls	94	100	93
D Gwynns Falls	100	97	59
E Loch Raven reservoir	7	62	0

Table 17. OCCURRENCE OF VIRUSES IN BACKGROUND SAMPLES

Sample site	Number of samples	Occurrence*, %				
		Animal Virus	Poliovirus	Coxsackie virus B	Echovirus	Other
A Raw sewage	15	93	53	53	20	13[a]
B Herring Run	11	82	36	36	27	0
C Jones Falls	12	75	33	58	8	8[b]
D Gwynns Falls	14	79	57	50	29	21[a, b]
E Loch Raven reservoir	7	71	43	29	14	14[c]

* - Occurrence based on presumptive test of virus concentrates

a - Adenovirus

b - Reovirus

c - Not identified

Table 18. DISTRIBUTION OF FECAL STREPTOCOCCI IN BACKGROUND SAMPLES*

	Occurrence Isolates, mean % (positive samples, %)			
	A	B	C	D
Fecal streptococci	Raw sewage	Herring Run	Jones Falls	Gwynns Falls
Enterococci	50.5 (100)	55.4 (100)	56.5 (100)	56.0 (100)
S. faecalis *S. faecium*	43.4 (100)	47.2 (97)	47.4 (100)	48.4 (97)
S. faecalis var. *liquefaciens zymogenes*	6.7 (74)	6.9 (70)	7.9 (59)	9.8 (58)
Atypical *S. faecalis*	0.4 (24)	1.4 (32)	0.6 (9)	0.5 (10)
S. bovis and *S. equinus*	9.9 (88)	8.7 (55)	7.8 (72)	7.5 (48)
False positive and non-fecal streptococci	37.0 (100)	34.3 (100)	34.7 (100)	36.0 (100)

* Insufficient data available for Loch Raven reservoir, sample site E.

Falls, respectively. False positive non-fecal streptococci were found in all the background samples and represented a mean of 34.4% to 37% of the isolates tested.

The geometric mean densities for the microorganisms assayed for each background sample station are given in Table 19. The raw sewage and Loch Raven reservoir provide information on the microbial water quality that can be expected under the worst and best conditions, respectively, in an urbanized area. Each of the urban streams contain high levels of each of the indicator microorganisms and would be judged contaminated regardless of the indicator of fecal contamination employed. The relative order of levels of pathogens in the urban streams was *P. aeruginosa* > *Staph. aureus* > Enterovirus > *Salmonella* sp. It should be stressed that the levels of enterovirus and *Salmonella* sp. are reported with a denominator 100-fold higher than the other microorganisms and represent a 100-fold more sensitive assay.

The relative levels of indicator and pathogenic microorganisms in the urban streams during the sampling period are shown graphically in the following three figures. Figure 24a shows the log density of each of the indicator groups of microorganisms by date for Herring Run (sample site B). Consistently high levels of total coliform, fecal coliform and fecal streptococci were observed throughout the year. Although variation can be seen in the data, there does not appear to be any marked variation with season. The levels of fecal coliform in Herring Run exceeded the recreational standard of 200 fecal coliforms/100 ml in 30 of 33 or 91% of the samples during the 13 month sampling period. The levels of pathogenic microorganisms in Herring Run can be seen in Figure 24b. Again, noticeable variation is shown but there is no apparent dependence upon season of the year. *Staph. aureus* was found at low levels in each sample. *Salmonella* sp. were consistently found in Herring Run and isolates were recovered in 27 of 32 or 84% of the samples.

The levels of indicator microorganisms in the Jones Falls are shown in Figure 25a. The total coliform, fecal coliform and fecal streptococci densities were somewhat higher than in Herring Run and no apparent seasonal variation was observed. All samples collected from the Jones Falls exceeded the fecal coliform recreational water standard by several orders of magnitude. The levels of *P. aeruginosa*, *Staph. aureus*, and *Salmonella* sp. (Figure 25b) are also considerably higher than in Herring Run. *P. aeruginosa* was the predominant pathogen followed by *Staph. aureus*. *Salmonella* was recovered from 29 of 31 or 94% of the samples collected from the Jones Falls.

Similar results are shown for Gwynns Falls in Figures 26a and 26b. High levels of indicators were observed with no apparent seasonal variation. The fecal coliform recreational water standard was met in only one sample during the sample period. The levels of pathogens follow the same order as in the previous urban streams. Seasonal variation again does not appear. A possible peak was observed for *P. aeruginosa* for the Gwynns Falls in September 1974 but was not observed in September of 1975. *Salmonella* was recovered from all samples collected in the Gwynns Falls.

Table 19. GEOMETRIC MEAN DENSITIES OF SELECTED PATHOGENS AND INDICATOR MICROORGANISMS IN BACKGROUND SAMPLES

Sample site	Enterovirus PFU/10 l.	*Salmonella* sp. MPN/10 l.	*P. aeruginosa* MPN/100ml	*Staph. aureus* MPN/100ml	Total coliform MPN/100ml	Fecal coliform MPN/100ml	Fecal strep. no./100ml	Enterococci no./100ml
A Raw sewage	8.7×10^2	5.0×10^2	2.3×10^5	2.6×10^2	2.3×10^7	6.3×10^6	1.2×10^6	5.4×10^5
B Herring Run	2.8×10^1	4.6	2.9×10^2	3.2	4.8×10^3	1.1×10^3	1.6×10^3	5.9×10^2
C Jones Falls	6.0×10^1	9.1	2.1×10^3	9.5	4.0×10^4	1.5×10^4	1.6×10^4	4.9×10^3
D Gwynns Falls	1.3×10^1	1.5×10^1	4.7×10^2	4.5	4.0×10^4	5.9×10^3	1.7×10^3	8.9×10^2
E Loch Raven reservoir	5.9×10^1	0	3.1	2.5	2.6×10^1	1.5×10^1	1.0×10^1	2.0

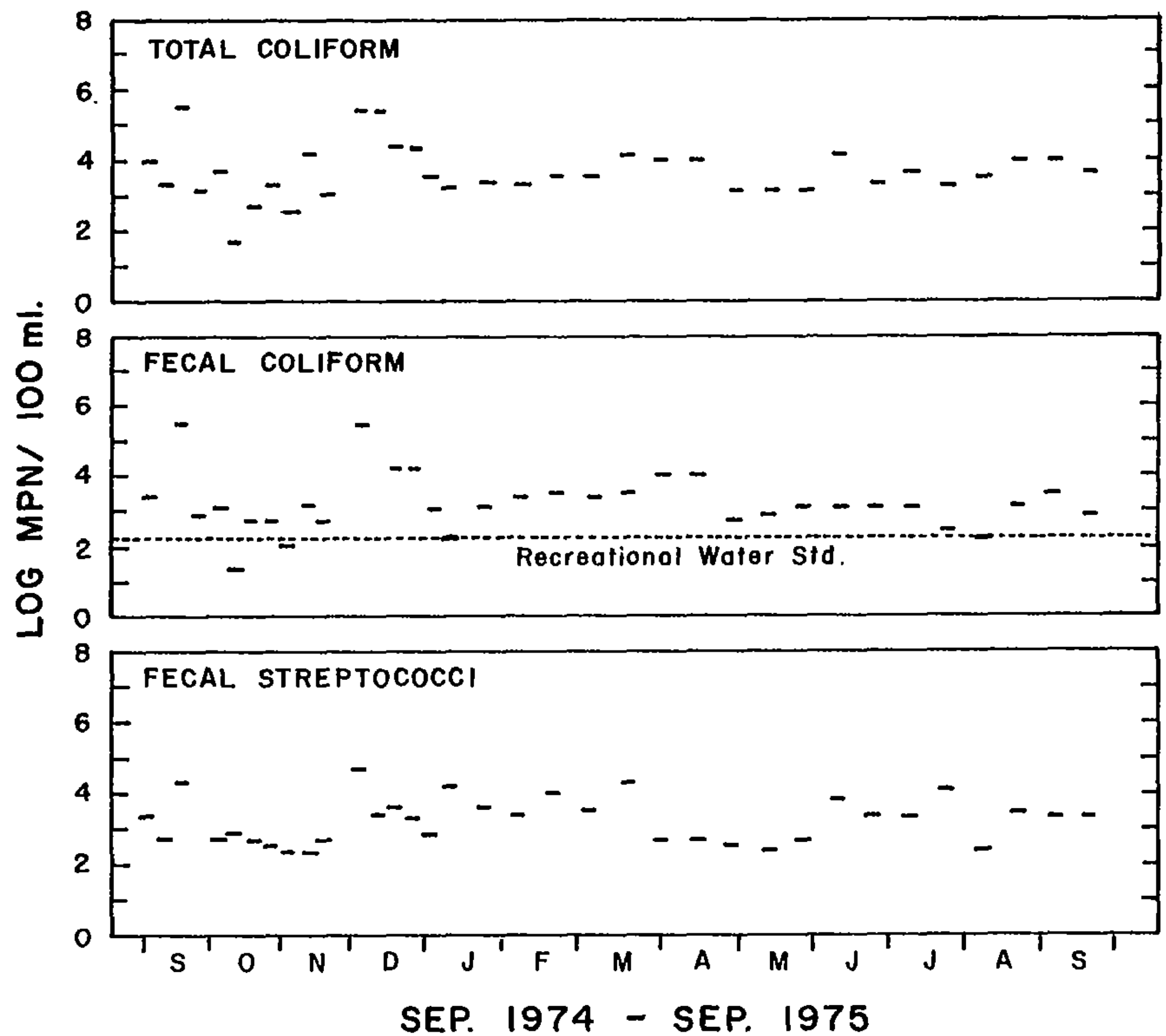


Figure 24a. Levels of indicator microorganisms in Herring Run, sample site B, during the sampling period.

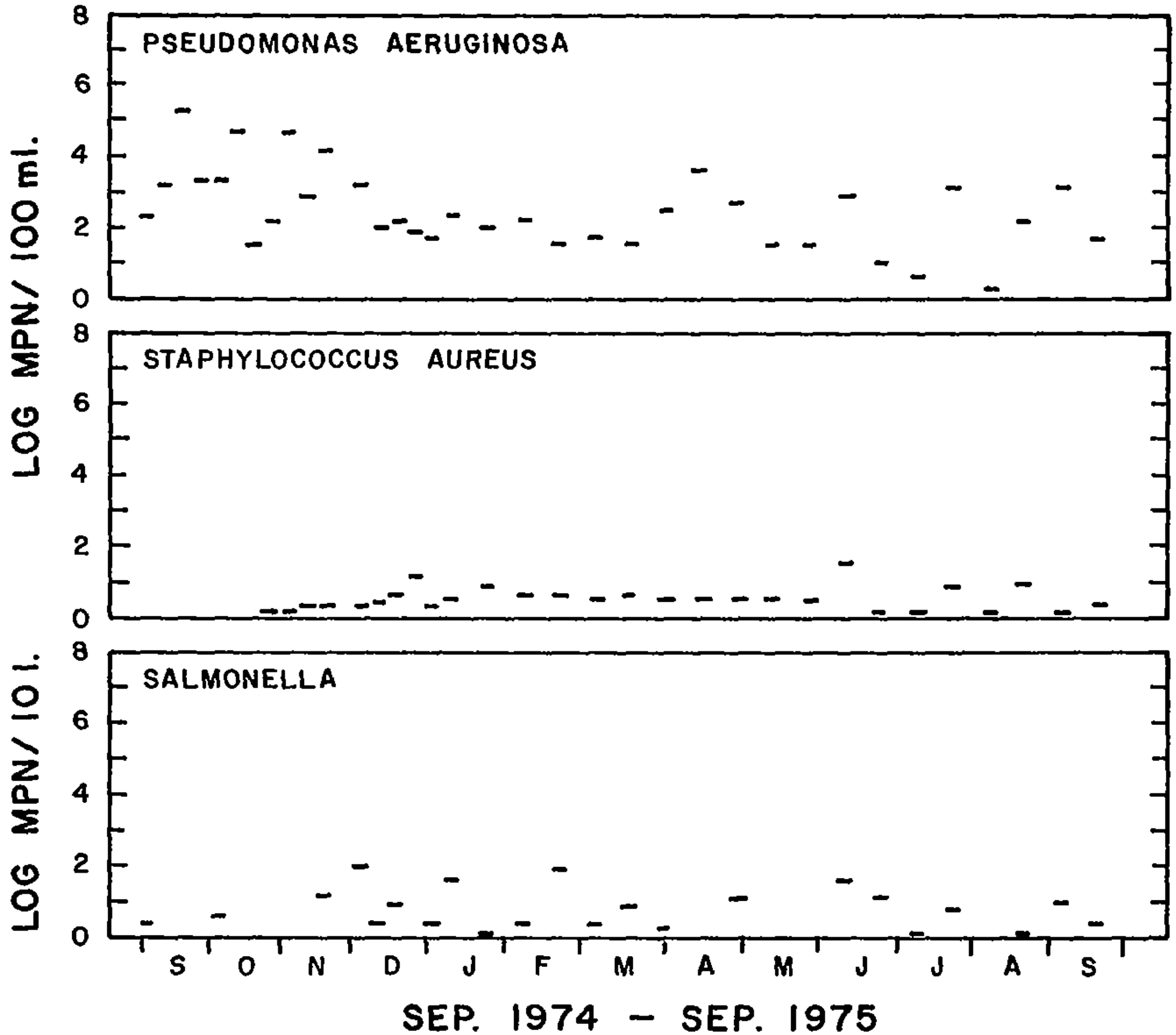


Figure 24b. Levels of pathogenic microorganisms in Herring Run, sample site B, during the sampling period.

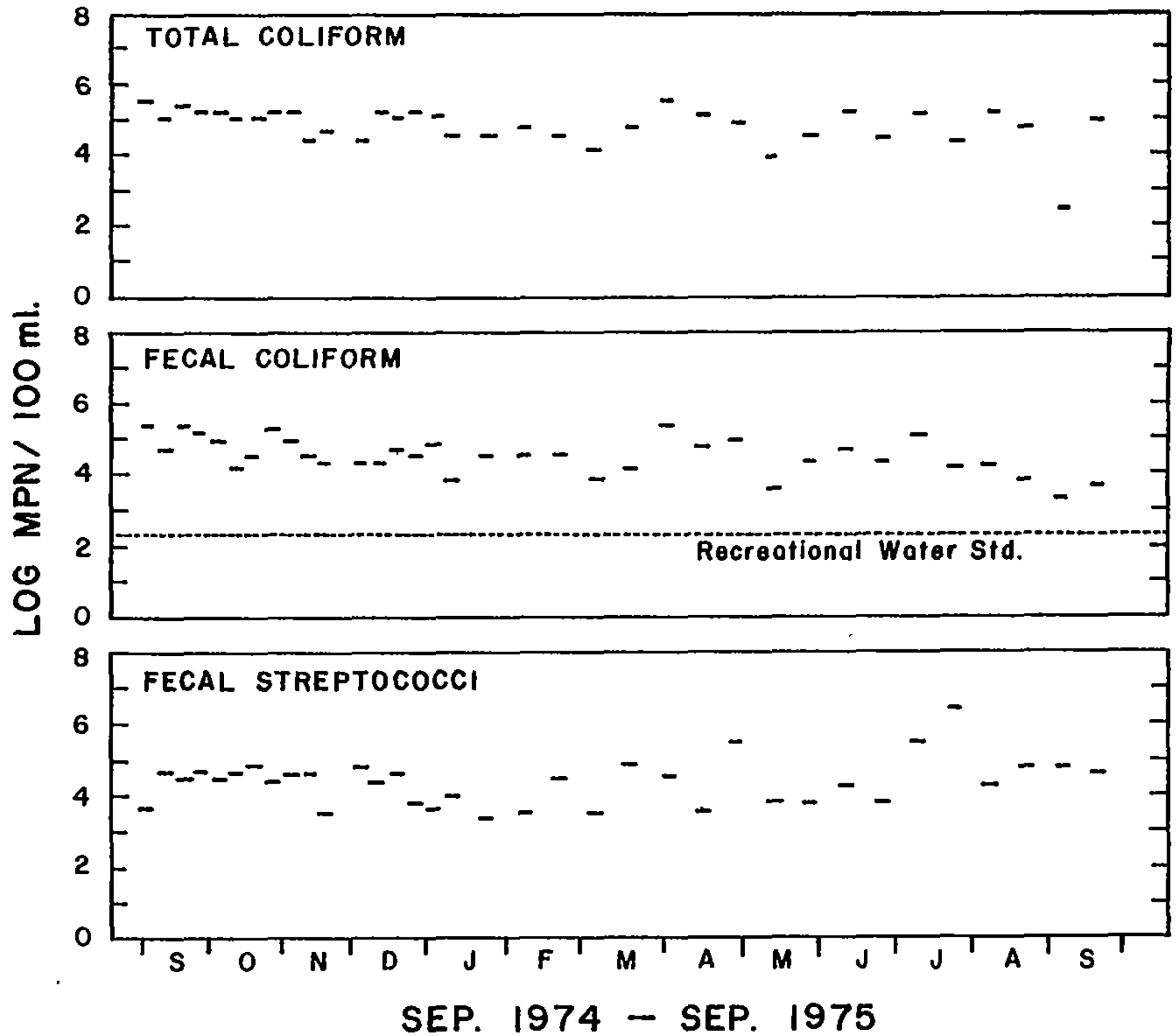


Figure 25a. Levels of indicator microorganisms in Jones Falls, sample site C, during the sampling period.

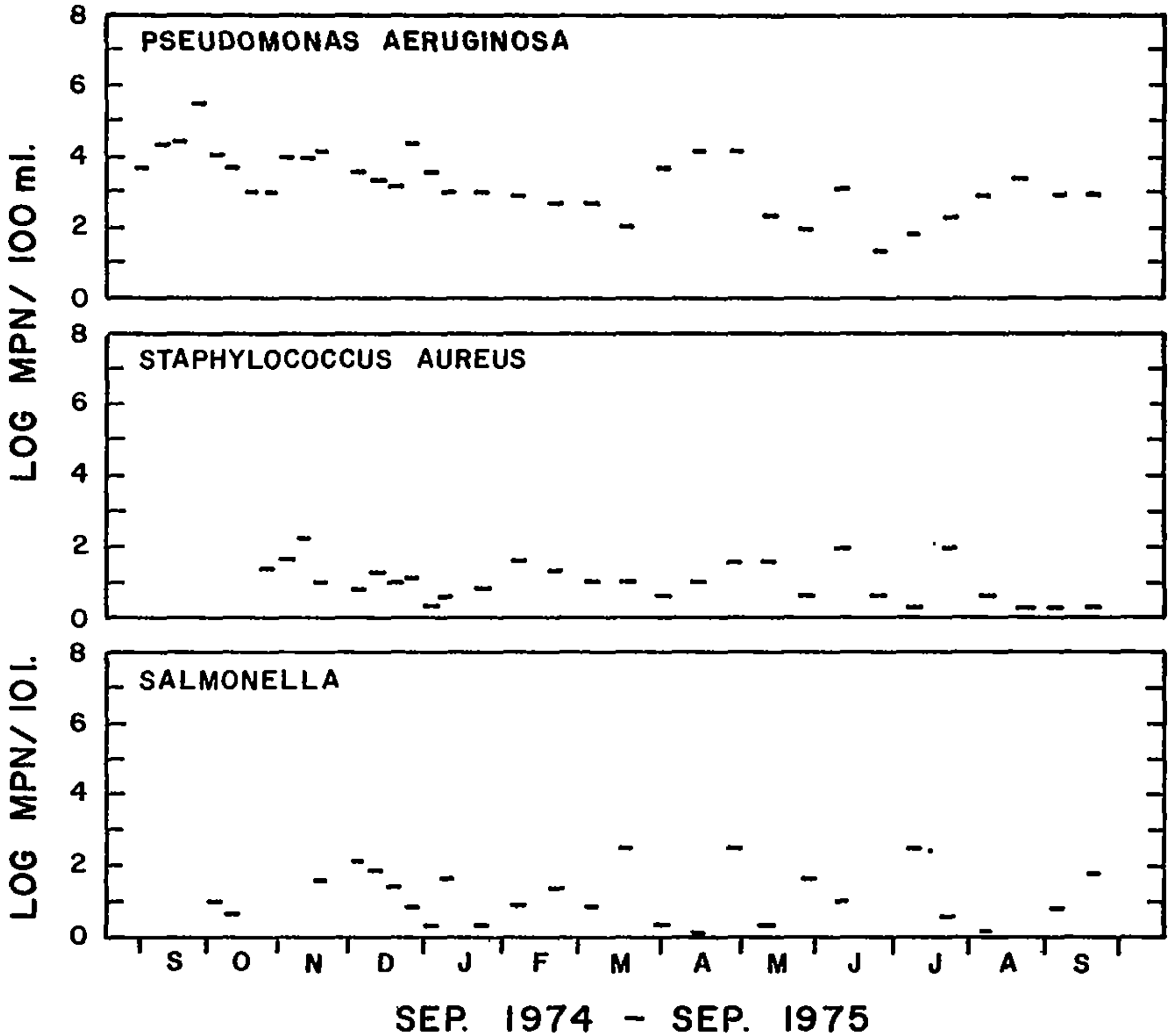


Figure 25b. Levels of pathogenic microorganisms in Jones Falls, sample site C, during the sampling period.

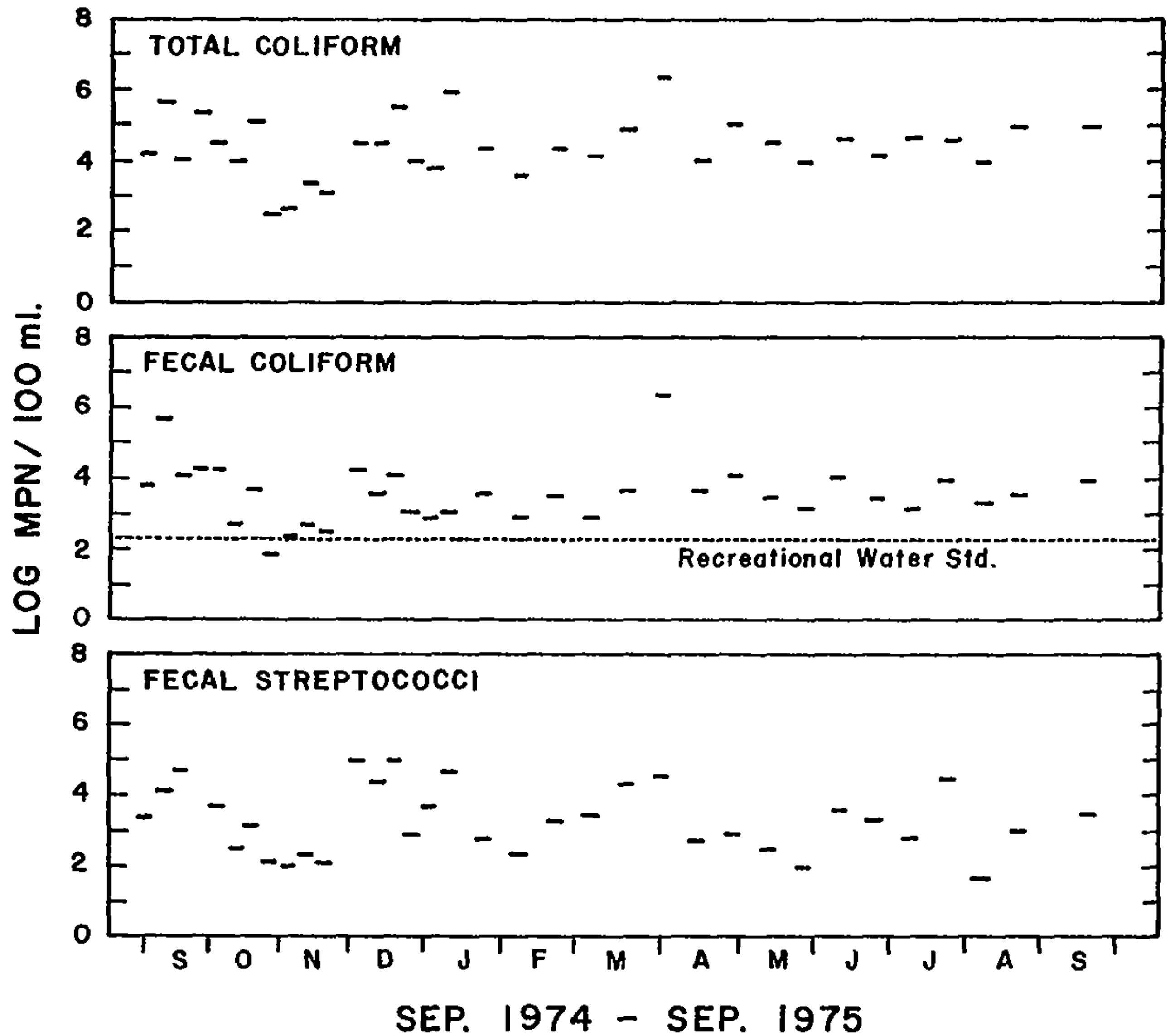


Figure 26a. Levels of indicator microorganisms in Gwynns Falls, sample site D, during the sampling period.

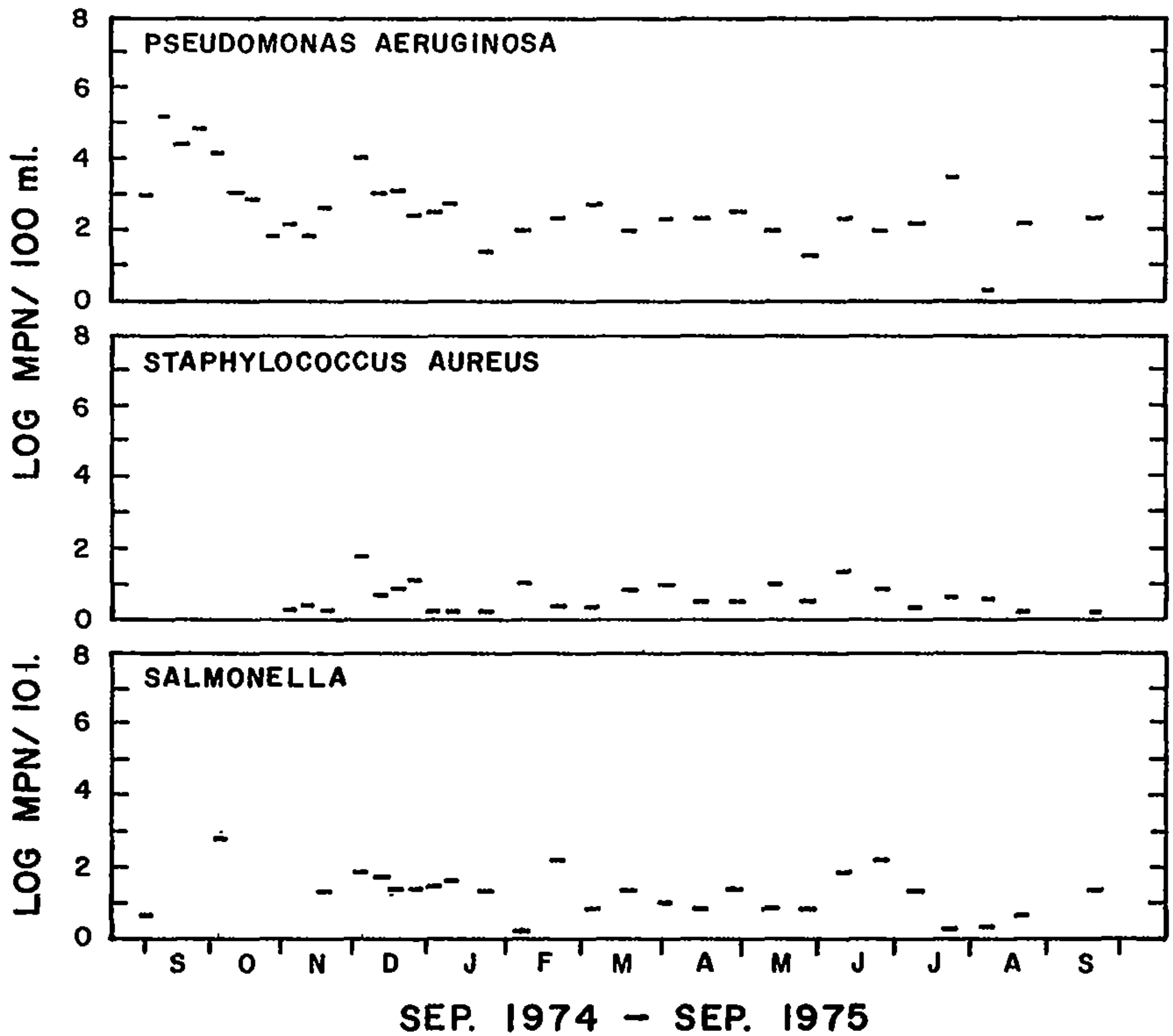


Figure 26b. Levels of pathogenic microorganisms in Gwynns Falls, sample site D, during the sampling period.

The effect of stream flow on the levels of fecal coliforms in Herring Run and Gwynns Falls is shown in Figures 27 and 28, respectively. Stream flow was determined at the time of sample collection. The minimum stream flow that could be estimated at Herring Run was 28 l/sec. (0.95 cfs). The highest recorded flow was 608 l/sec. (21.5 cfs) and is not recorded on the graph. During periods of low flow the levels of fecal coliform varied from just more than 10 to greater than 10^5 MPN/100 ml. There was no apparent relationship between stream flow and fecal coliform densities for Herring Run. The stream flow in the larger Gwynns Falls varied from 110 to 8,490 l/sec. (3.9 to 300 cfs). As in Herring Run, there appears to be little correlation between stream flow and levels of fecal coliforms.

The effect of previous rainfall prior to the time of sampling on the microbial quality was evaluated for the background samples. The levels of fecal coliform was compared to the antecedent or number of days since the last rainfall. Antecedent rainfall, in days, appears to have little effect on the fecal coliform density in raw sewage and urban streams (Figure 29).

Storm Samples

The occurrence of selected pathogenic bacteria in storm runoff is shown in Table 20. *Salmonella* sp. were recovered from all the samples collected at Stoney Run, Glen Avenue, and Howard Park, 96% of the samples collected at Jones Falls storm drain and Bush Street, and 52% of the Northwood samples. *P. aeruginosa* was found in all the storm samples at levels approaching those found for the indicator microorganisms. *Staph. aureus* was isolated from 83%, 71%, 95%, 100%, 96%, and 82% of the samples from Stoney Run, Glen Avenue, Howard Park, Jones Falls storm drain, Bush Street and Northwood, respectively. The lower relative recovery of *Staph. aureus* was due to the higher sensitivity limit for the *Staph. aureus* assay. No concentration procedure was employed and the maximum sample volume assayed was 10 ml.

Animal viruses were recovered at a high frequency in the storm runoff samples. Table 21 shows the occurrence of selected animal viruses for these samples. Animal viruses were recovered from all the samples at Stoney Run and Howard Park, 92% of the Glen Avenue, 83% of the Jones Falls and Northwood and 75% of the Bush Street samples. The predominant virus groups found were polioviruses and Coxsackie B viruses. Echovirus was observed at a lower frequency. Adenovirus was found in 1 of 12 samples at Bush Street and reoviruses were found at a similar frequency at Glen Avenue and Howard Park.

The distribution of fecal streptococci in the storm runoff samples is given in Table 22. The mean percent of isolates that were found for each component of the fecal streptococci for each storm sample site is shown. The number in parenthesis was the frequency with which the member microorganisms were observed. Enterococci were found in all samples and were 39.6% to 51.5% of the isolates tested. The major portion of the enterococcal group were typical strains of *S. faecalis* and *S. faecium*. A small percentage (1.3% - 7.1%) of the enterococci isolates were the *liquefaciens - zymogenes* varieties of *S. faecalis*

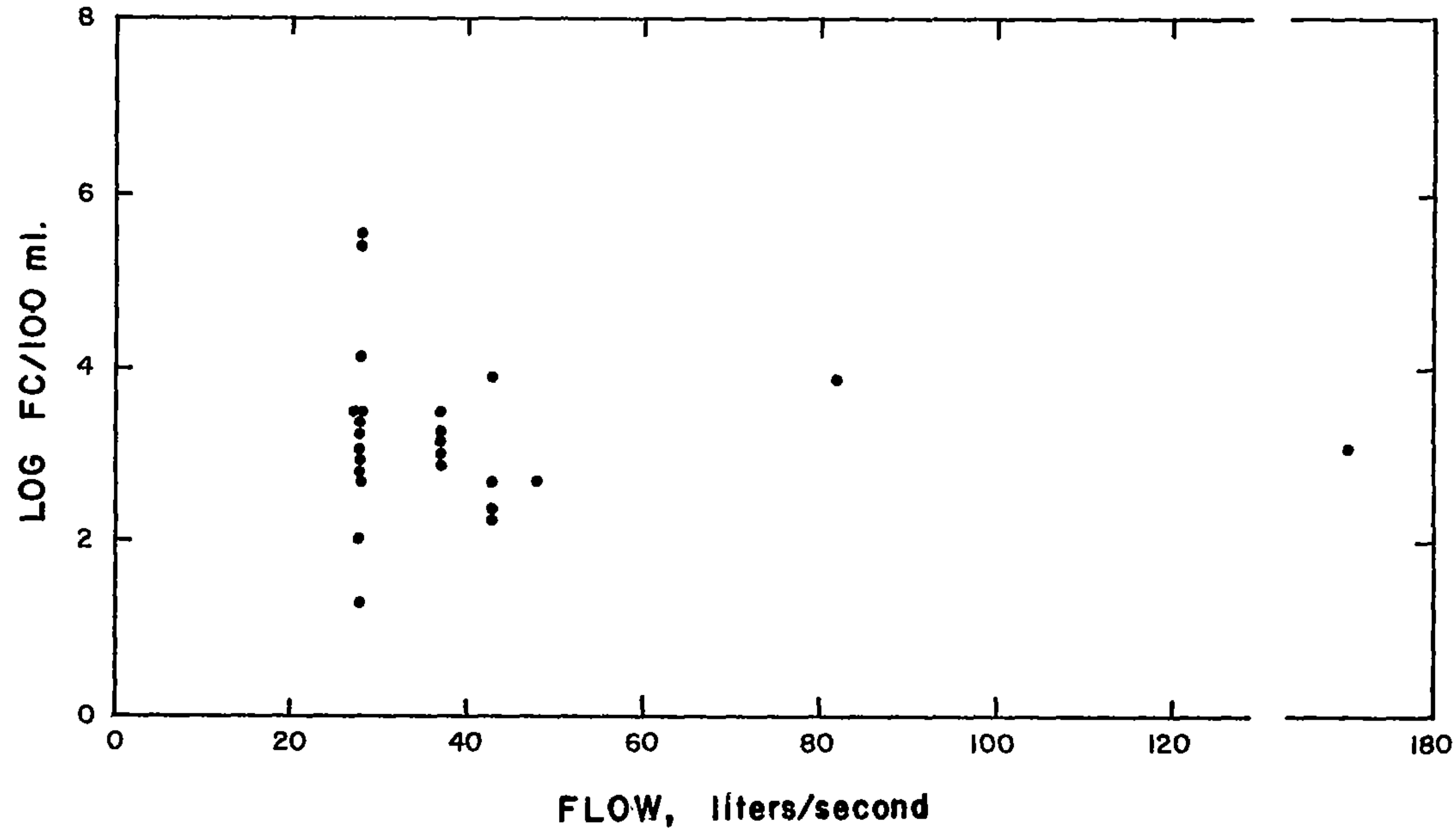


Figure 27. Effect of stream flow on the levels of fecal coliform in Herring Run, sample site B.

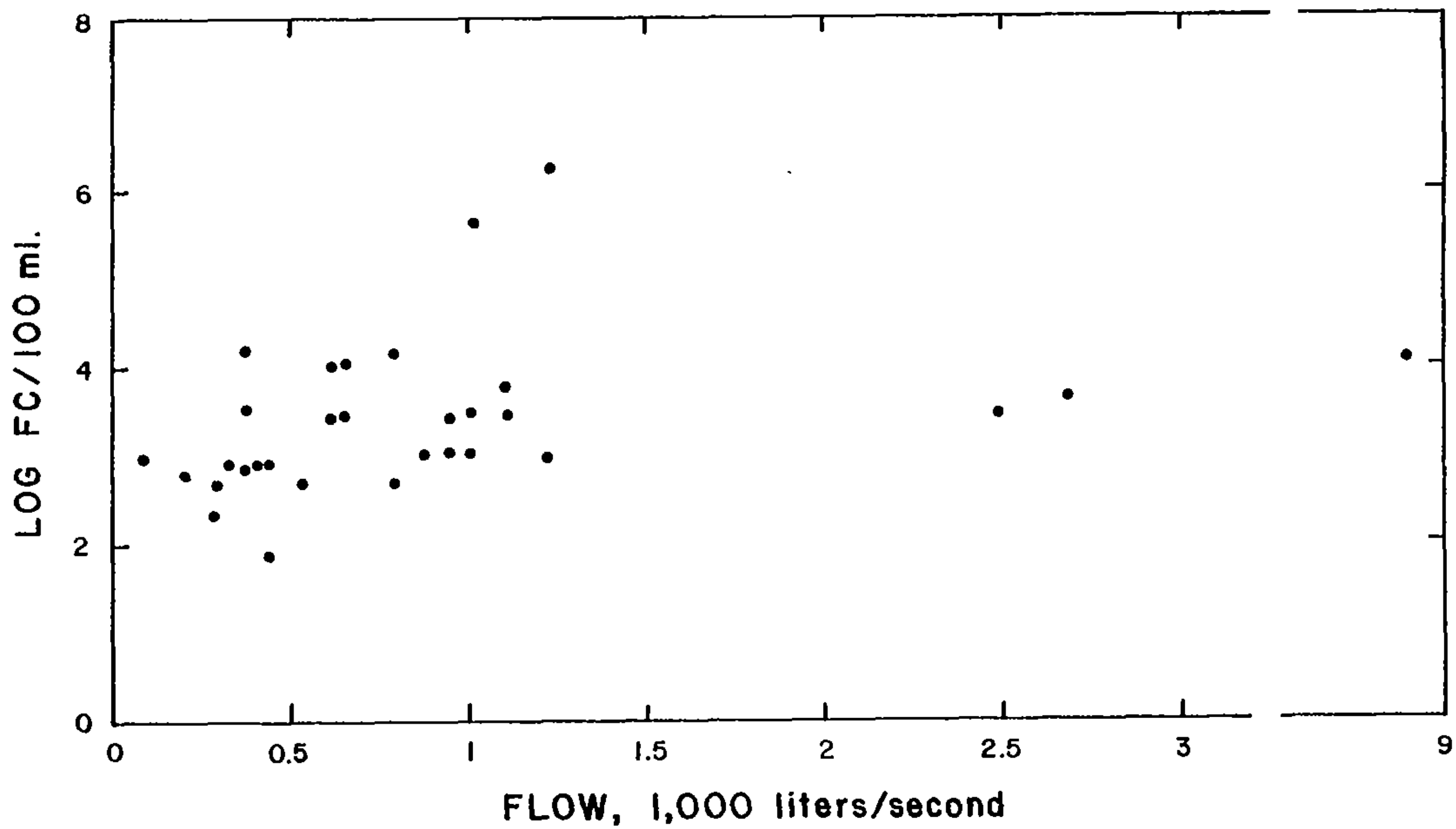


Figure 28. Effect of stream flow on the levels of fecal coliform in Gwynns Falls, sample site D.

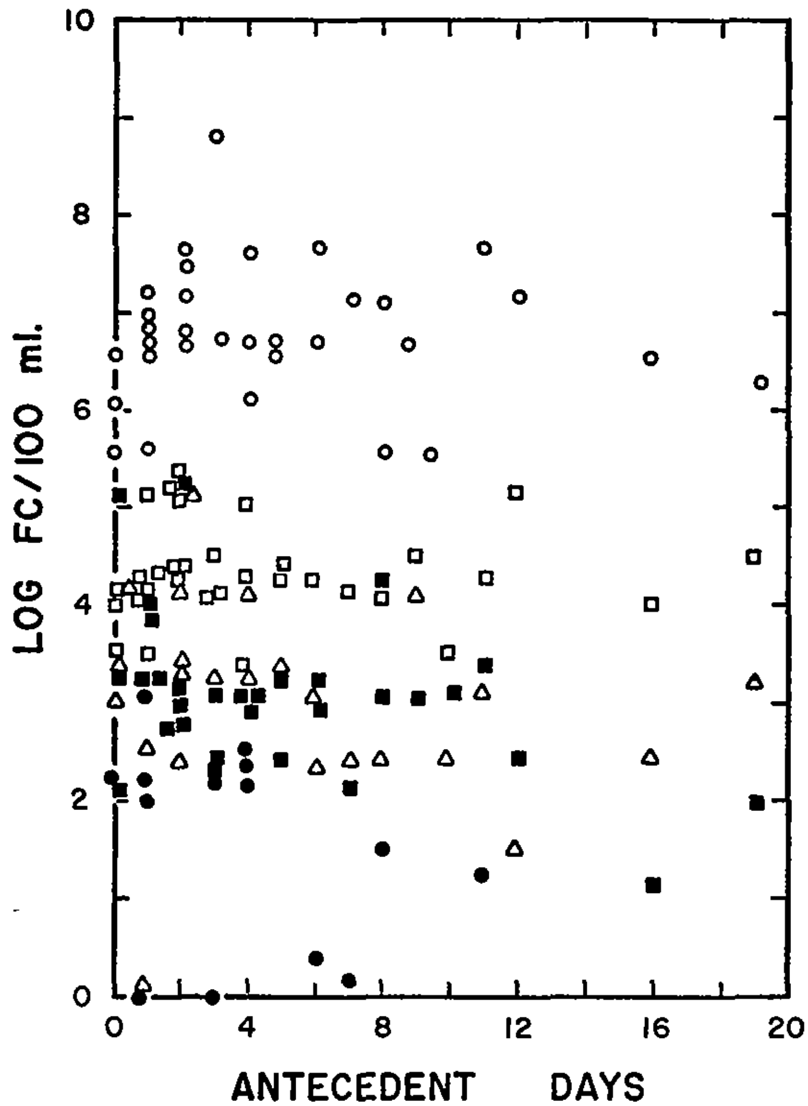


Figure 29. The effect of period in days since last rain storm on the fecal coliform density measured in the background samples, A, raw sewage (o), B, Herring Run (■), C, Jones Falls (□), D, Gwynns Falls (△), and E, Loch Raven (●).

Table 20. OCCURRENCE OF SELECTED PATHOGENIC BACTERIA IN STORMWATER SAMPLES

Sample site	Occurrence, %		
	Salmonella sp.	*P. aeruginosa*	*Staph. aureus*
F Stoney Run	100	100	83
G Glen Avenue	100	100	71
H Howard Park	100	100	95
K Jones Falls storm drain	96	100	100
L Bush Street	96	100	96
M Northwood	52	100	82

Table 21. OCCURRENCE OF SELECTED VIRUSES IN STORMWATER SAMPLES

Sample site	Occurrence, %				
	Animal virus	Poliovirus	Coxsackie virus B	Echovirus	Other
F Stoney Run	100	73	73	27	9[c]
G Glen Avenue	92	75	42	17	8[b]
H Howard Park	100	42	58	8	8[b]
K Jones Falls storm drain	83	67	50	33	8[c]
L Bush Street	75	25	42	25	8[a]
M Northwood	83	42	50	33	8[c]

a - Adenovirus

b - Reovirus

c - Not identified

Table 22. DISTRIBUTION OF FECAL STREPTOCOCCI IN STORMWATER SAMPLES

Fecal streptococci	Occurrence Isolates, mean % (positive samples, %)					
	F Stoney Run	G Glen Avenue	H Howard Park	K Jones Falls storm drain	L Bush Street	M Northwood
Enterococci	45.4 (100)	38.8 (100)	39.7 (100)	40.4 (100)	39.6 (100)	51.5 (100)
S. faecalis *S. faecium*	38.0 (100)	37.4 (100)	33.6 (100)	32.6 (91)	32.8 (100)	46.7 (100)
S. faecalis var. *liquefaciens* and *zymogenes*	6.3 (62)	1.3 (30)	5.4 (58)	7.1 (43)	6.0 (50)	4.4 (35)
Atypical S. faecalis	0.2 (10)	0.3 (10)	0.5 (21)	0.7 (24)	0.8 (20)	0.5 (18)
S. bovis and *S. equinus*	15.4 (67)	10.5 (65)	17.2 (84)	17.5 (91)	17.4 (85)	8.5 (65)
False positive and non-fecal streptococci	38.8 (95)	48.1 (100)	41.8 (100)	41.5 (100)	41.1 (100)	38.1 (100)

and were found in 10% to 24% of the samples. *S. bovis* and *S. equinus* were recovered in 65% to 91% of the storm samples and represent 10.5 to 17.5% of the isolates. The false positive and non-fecal streptococci were found in all the storm samples and were 38.8% to 48.1% of the isolates.

The geometric mean densities of the selected pathogens and indicator microorganisms for each storm sample site are given in Table 23 to provide an indication of the relative microbial quality of the storm runoff at each location. The levels of indicators, *P. aeruginosa* and *Staph. aureus* are reported in the conventional units of MPN or number/100 ml while the levels of enterovirus and *Salmonella* sp. are reported as PFU/10 1 and MPN/10 1, respectively. The levels of total coliform, fecal coliform, fecal streptococci and enterococci suggest that the runoff at each location was heavily contaminated and from a microbiological standpoint was of poor quality. The densities of indicator microorganisms found in storm runoff were generally about 10-fold higher than that found in urban streams and approached the indicator densities of raw sewage. The levels of indicators in storm runoff was several orders of magnitude above that found in the reservoir samples. Regardless of the indicator employed, the runoff from each of the sample locations would be considered heavily contaminated. With the exception of Howard Park (H) and Northwood (M) the mean levels of indicators are surprisingly similar. The Howard Park sample, representative of a true combined system, contained consistently higher levels of indicators than the other stormwaters. Northwood, a small drainage area of storm runoff only, contained consistently lower levels of indicators than from the remaining runoff sites. The Jones Falls storm drain is known to receive some raw sewage but the ratio of raw sewage to runoff is believed to be small. The Stoney Run (F) and Glen Avenue (G) drainage areas contain bleeders from the sanitary sewers which occasionally operate during heavy rain storms. The Bush Street drain (L), although believed to carry only storm runoff, has a large low lying catchment area with many possibilities for sewage contamination.

The stormwater levels of enteroviruses, *Salmonella* sp., *P. aeruginosa* and *Staph. aureus* were several fold higher than that found in the urban streams but significantly lower than the levels in raw sewage. *P. aeruginosa* was the most predominant pathogen in stormwater followed by *Staph. aureus*, enteroviruses, and *Salmonella* sp. Howard Park samples from the combined sewer yielded considerably higher levels of pathogenic microorganisms than the other sampling locations.

Fairly reliable flow estimations were obtained at the time of sampling for three stations; Stoney Run (F), the Jones Falls storm drain (K), and the Northwood storm drain (M). Flow estimation at the remaining three stations were unreliable due to surcharging, loss of a velocity meter and washouts. Figure 30 shows the relationship of instantaneous flows to the levels of fecal coliforms determined at the time of sample collection for Stoney Run, the Jones Falls storm drain and Northwood. At low flows the range of levels of fecal coliforms was between 10^2 to almost 10^6/100 ml. A similar range of fecal coliform density was observed at moderate and high flows. There appeared to be little correlation between instantaneous discharge and the levels of microorganisms.

Table 23. GEOMETRIC MEAN DENSITIES OF SELECTED PATHOGENS AND INDICATOR MICROORGANISMS IN STORMWATER

Sample site	Enterovirus PFU/10 l.	*Salmonella* sp. MPN/10 l.	*P. aeruginosa* MPN/100ml	*Staph. aureus* MPN/100ml	Total coliform MPN/100ml	Fecal coliform MPN/100ml	Fecal strep. no./100ml	Enterococci no./100ml
F Stoney Run	1.9×10^2	3.0×10^1	1.3×10^3	1.2×10^1	4.8×10^4	1.9×10^4	4.1×10^4	1.4×10^4
G Glen Ave.	7.5×10^1	2.4×10^1	3.3×10^3	1.4×10^1	2.4×10^5	8.1×10^4	6.6×10^5	2.1×10^5
H Howard Park	2.8×10^2	1.4×10^2	5.2×10^3	3.6×10^1	1.2×10^6	4.5×10^5	2.4×10^5	5.9×10^4
K Jones Falls storm drain	3.0×10^1	2.5×10^1	6.6×10^3	4.0×10^1	2.9×10^5	1.2×10^5	2.8×10^5	8.7×10^4
L Bush St.	6.9	3.0×10^1	2.0×10^3	1.2×10^2	3.8×10^5	8.3×10^4	5.6×10^5	1.2×10^5
M Northwood	1.7×10^2	5.7	5.9×10^2	1.2×10^1	3.8×10^4	6.9×10^3	5.0×10^4	2.1×10^4

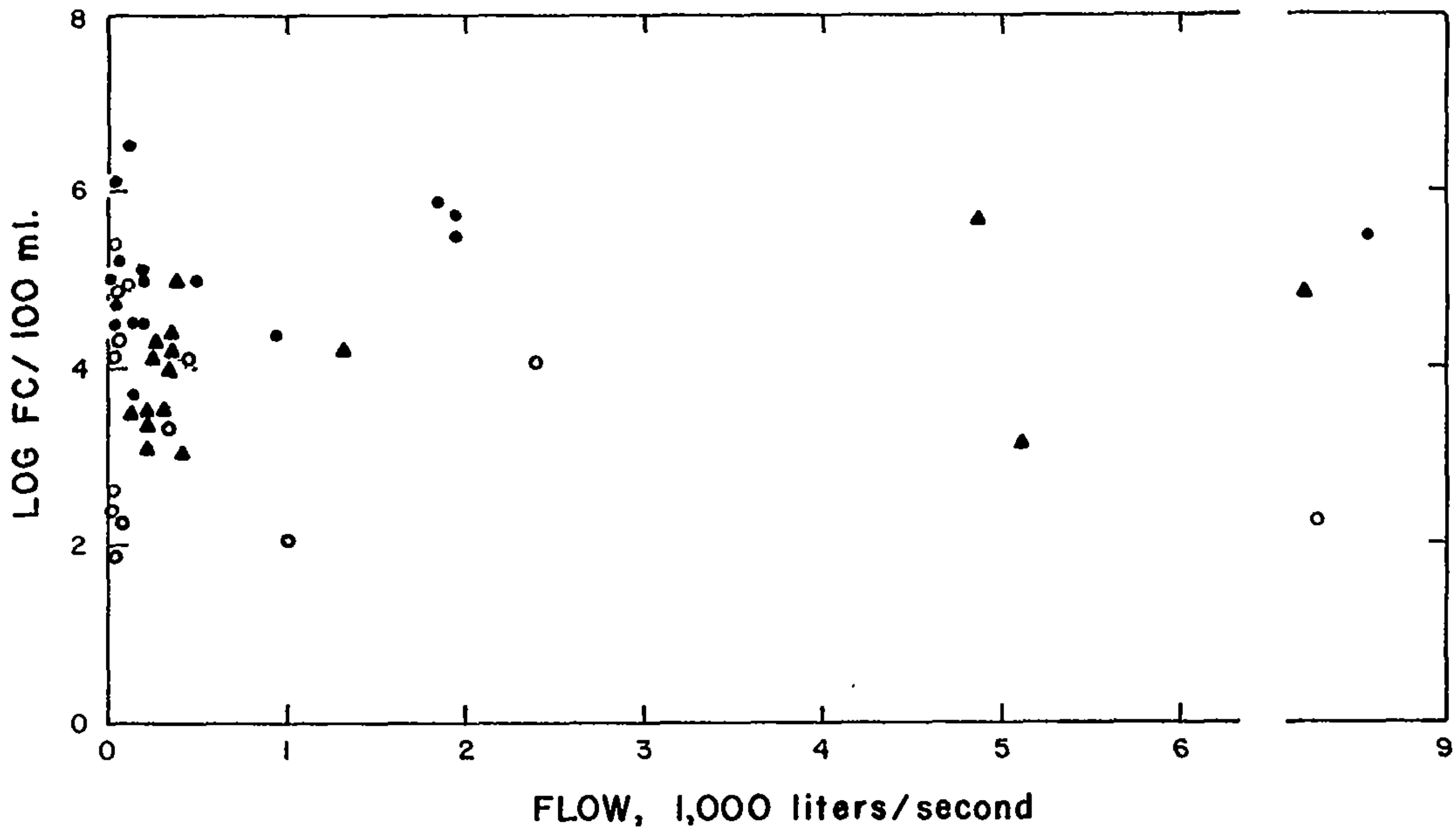


Figure 30. The relationship of stream flow at the time of sampling on the fecal coliform density in stormwater at F, Stoney Run (▲), K, Jones Falls (●), and M, Northwood (o).

The effect of the number of days since the last storm on the levels of fecal coliform is shown in Figure 31. Similar to that observed for the background samples, the levels of fecal coliform observed in the storm runoff appears to be independent of the time between storms.

RELATIONSHIP BETWEEN PATHOGENS AND INDICATORS

The relationship between indicator and pathogenic microorganisms was evaluated in the following Figures 32 through 35. The logarithm of the density of the pathogen was compared to the logarithm of the density of the indicator group of microorganisms for all samples. The lower sensitivity limit of the pathogen determination is a function of the volume of sample assayed. In cases where no pathogen was recovered the lower sensitivity limit was about one microorganism per unit volume. For purposes of graphic representation and statistical analysis the value of one was assigned to these samples. Since the logarithm of one is zero, the minimum detectable concentration points were plotted as zero logs in the graphs. Lines of best fit for background and storm samples were calculated by the method of least squares and presented on each graph. The correlation coefficients, r, were calculated for four groups of samples; all, background, storm and stream. These are presented in the upper left hand corner of each graph. In addition the 99% confidence intervals for each value of r are shown. The linear relationship between the levels of indicator and pathogenic microorganisms was tested by evaluating the null hypothesis for the correlation coefficient (r = 0). The significance of r was tested using the lower limit of the 99% confidence interval for r. Conclusions indicating a linear relationship are affected by the number of pairs of samples and the magnitude of r. The number of pairs for sample groups varied slightly for each comparison of pathogens and indicators. The numbers of the pairings of pathogenic bacteria and various indicators in the analysis for all, background, storm and stream samples were in the ranges 218 to 266, 119 to 136, 112 to 130 and 70 to 93, respectively.

The relationships between the levels of *Salmonella* sp. and total coliform, fecal coliform, fecal streptococci and enterococci are shown in Figures 32a, b, c, and d, respectively. The levels of *Salmonella* are presented as MPN/10 1 and the levels of indicators are presented as MPN or number/100 ml. Thus, it should be recognized that the levels of *Salmonella* are 100-fold lower than the levels of indicator microorganisms. The data show considerable variation. However, the positive linear relationships between indicators and *Salmonella* for all the samples are unmistakable. The correlation coefficients for total coliform, fecal coliform, fecal streptococci and enterococci were 0.54, 0.59, 0.53 and 0.54, respectively, and are significant at the 1% level. There appears to be a reasonably good correlation between indicator and *Salmonella* for the overall data. Although fecal coliforms yielded the highest correlation coefficient, each of the indicator groups tested gave good linear relationships to the levels of *Salmonella*. The correlation coefficients for the background samples: raw sewage, urban streams and reservoir, showed somewhat higher correlation coefficients. The r values of 0.67 for total coliform, 0.72 for fecal coliform, 0.71 for fecal streptococci and 0.73 for enterococci were also significant at the 1% level. Again, little difference was observed for the linear relationships between the indicator groups and *Salmonella*. However,

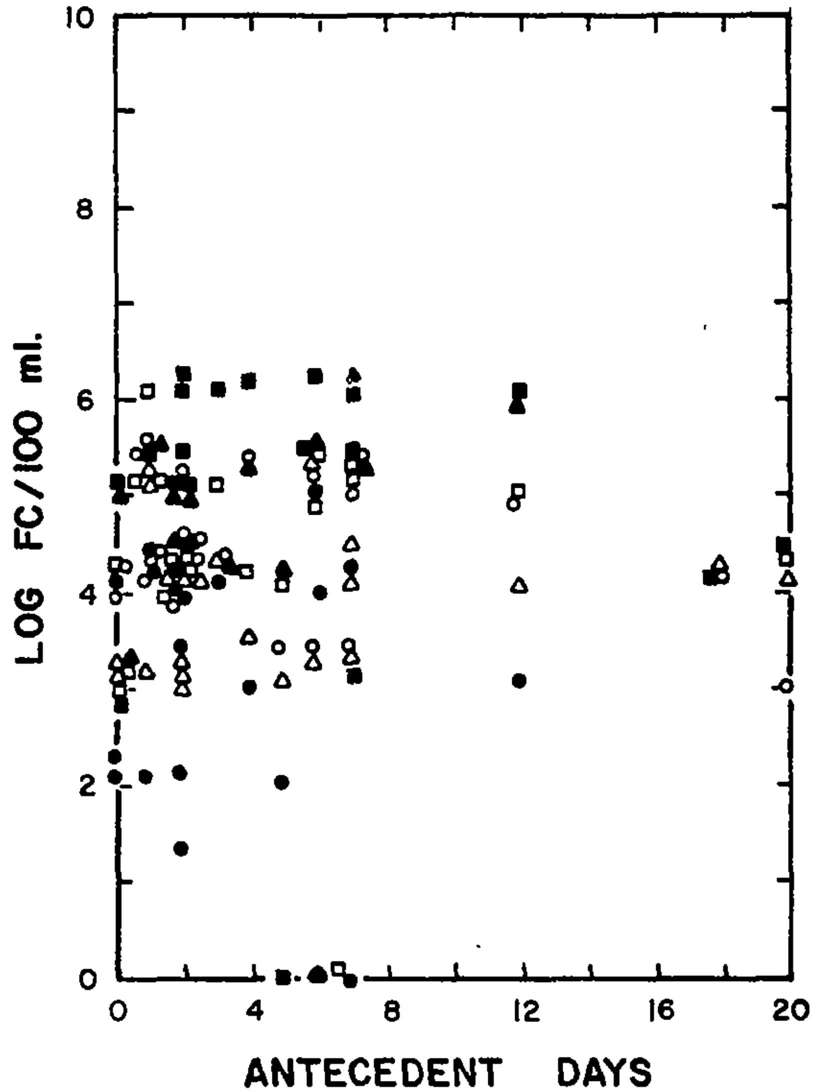


Figure 31. The effect of number of days since the last rainstorm on the fecal coliform density of stormwater at F, Stoney Run (△), G, Western Run (□), H, Howard Park (■), K, Jones Falls (▲), L, Bust St. (○), and M, Northwood (●).

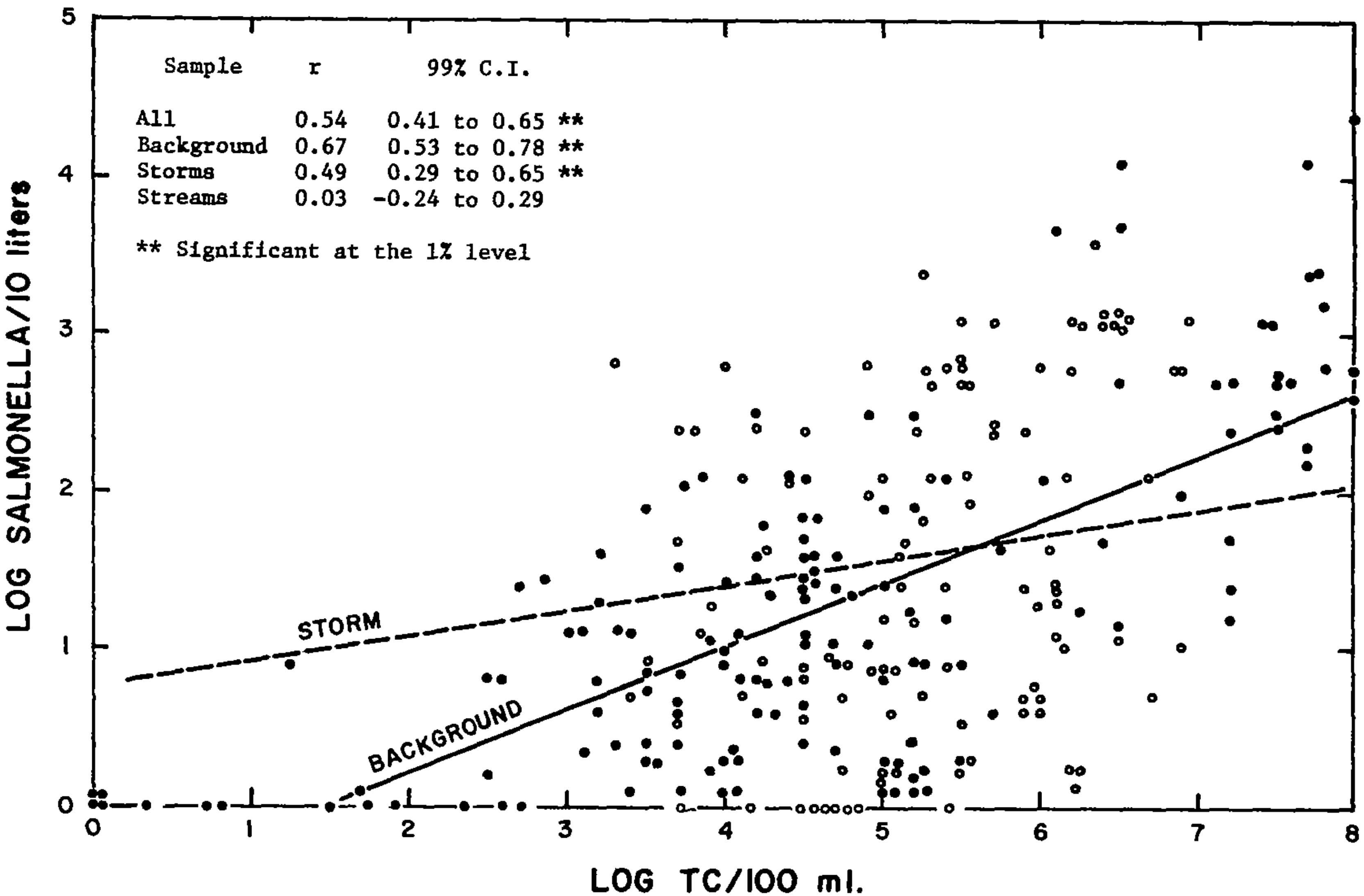


Figure 32a. Relationship between total coliform and *Salmonella* in background (solid point) and stormwater (open point) samples.

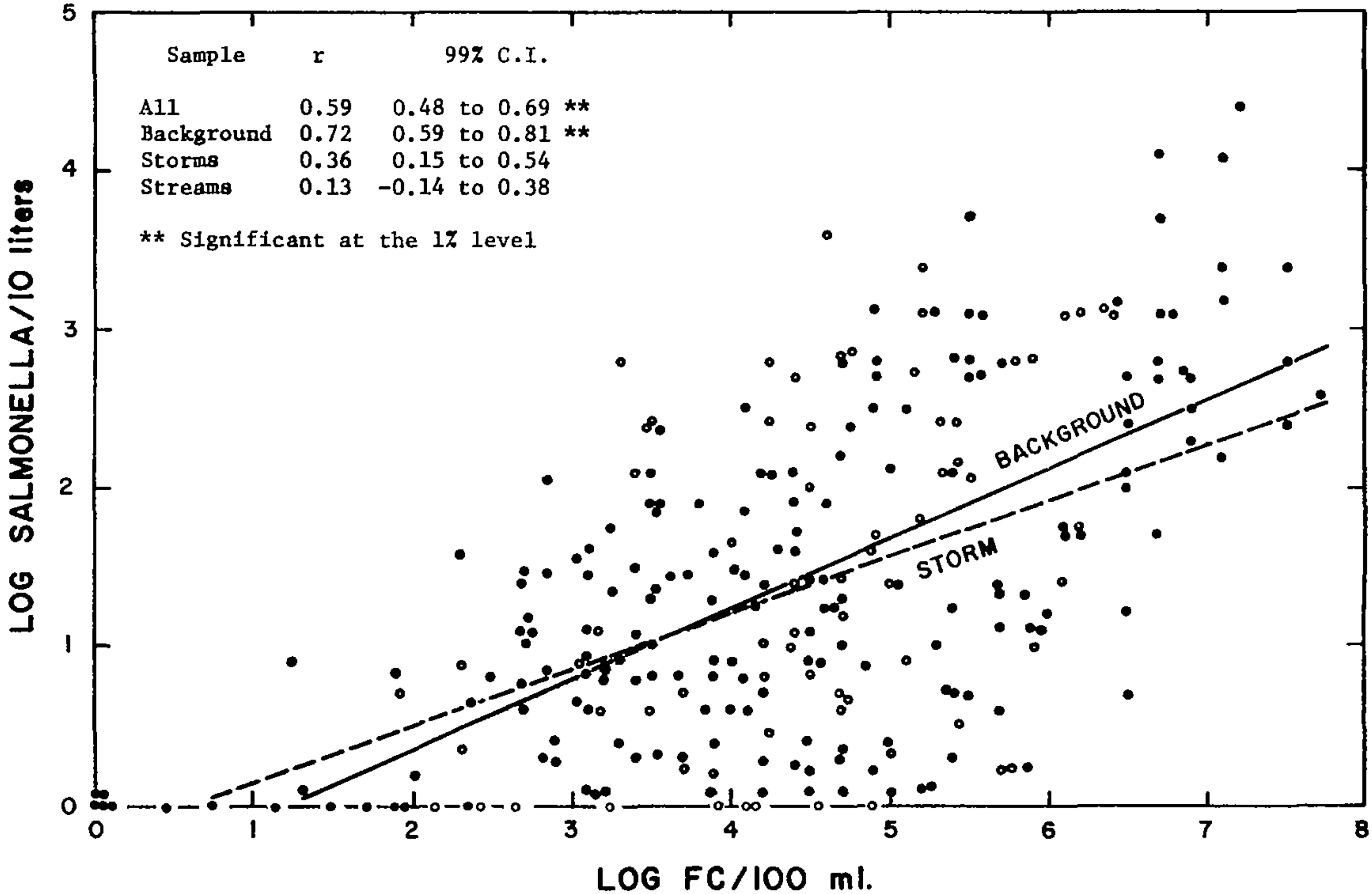


Figure 32b. Relationship between fecal coliform and *Salmonella* in background (solid point) and storm-water (open point) samples.

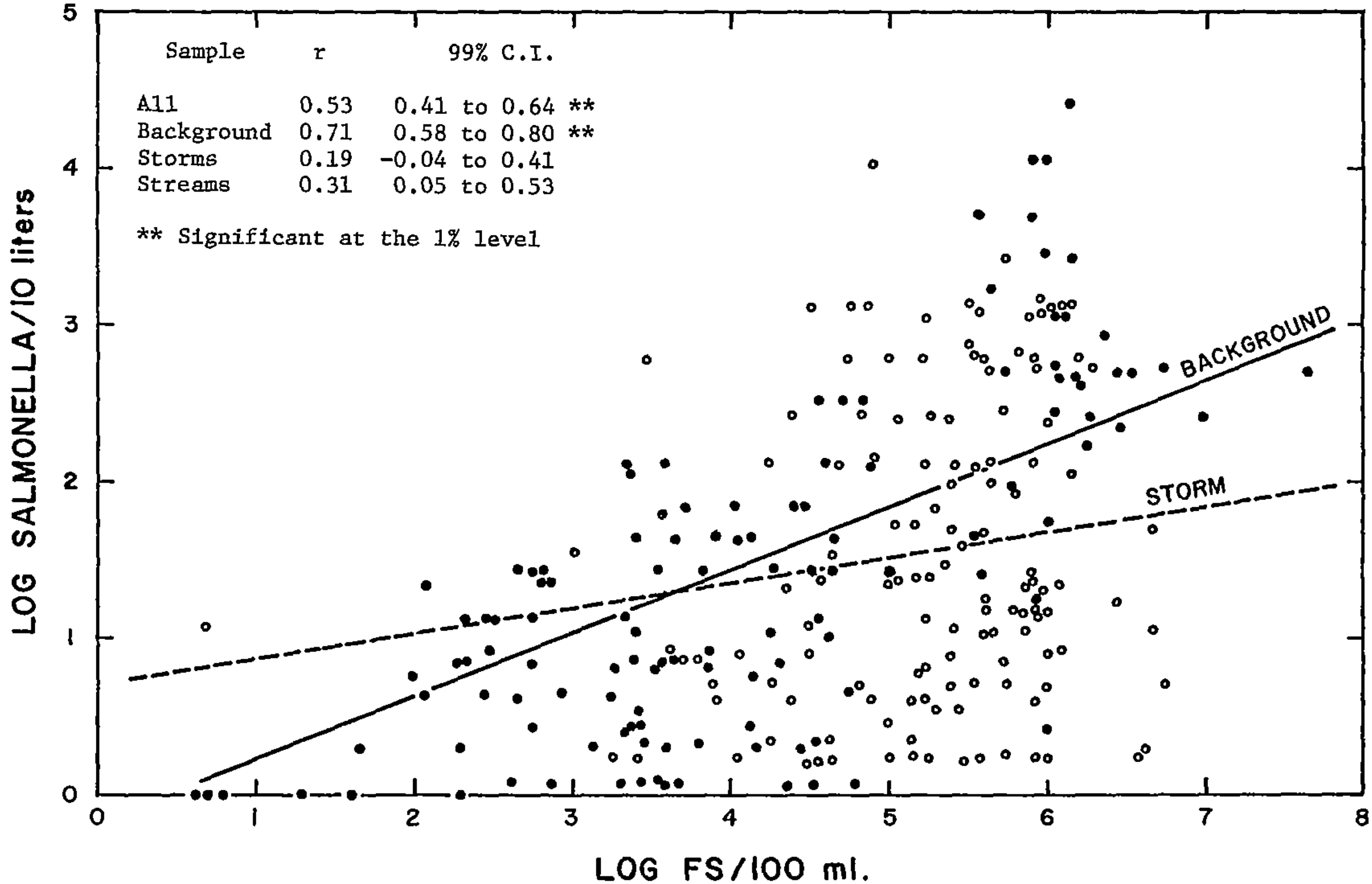
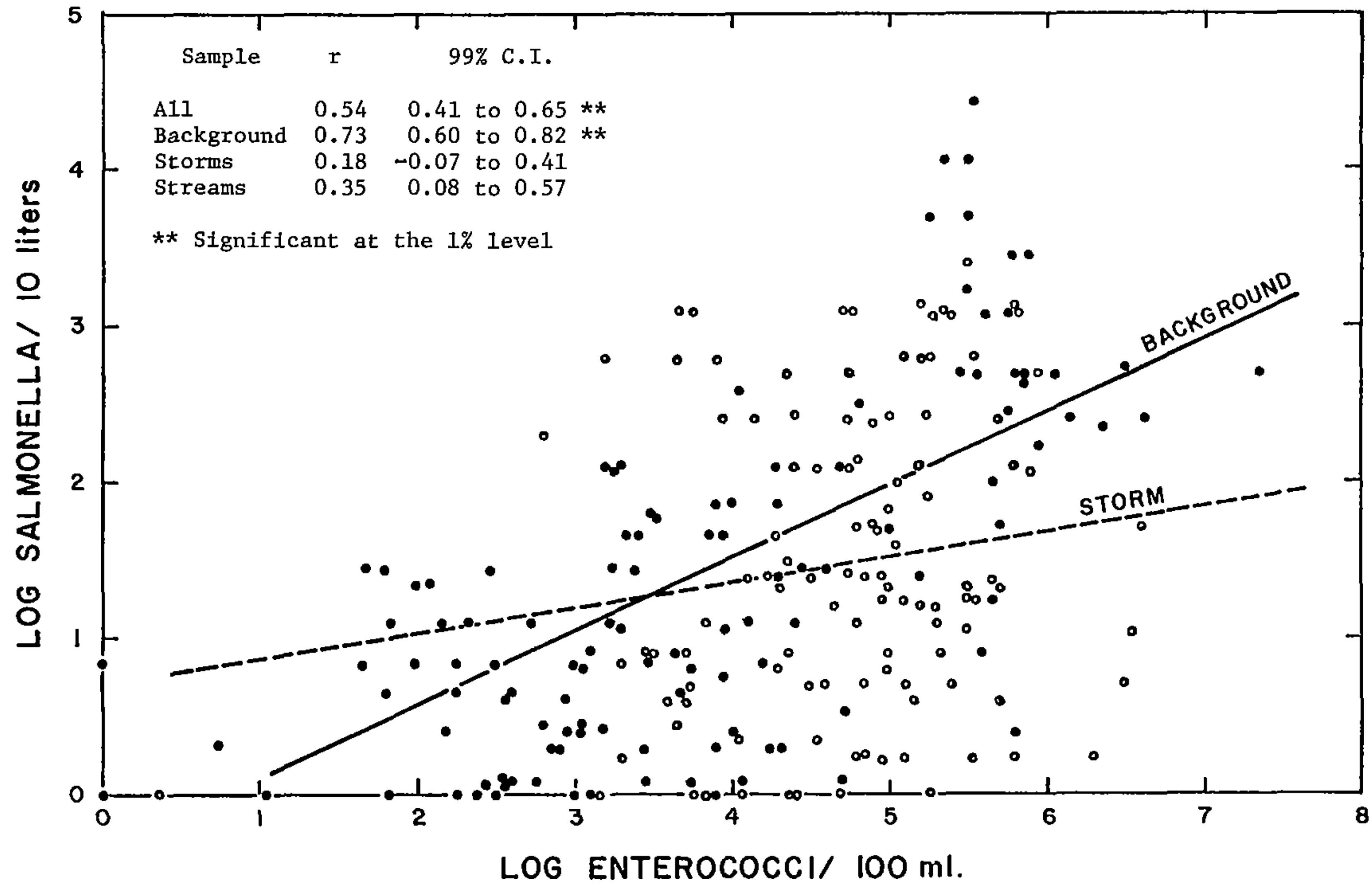


Figure 32c. Relationship between fecal streptococci and *Salmonella* in background (solid point) and stormwater (open point) samples.



Sample	r	99% C.I.
All	0.54	0.41 to 0.65 **
Background	0.73	0.60 to 0.82 **
Storms	0.18	-0.07 to 0.41
Streams	0.35	0.08 to 0.57

** Significant at the 1% level

Figure 32d. Relationship between enterococci and *Salmonella* in background (solid point) and stormwater (open point) samples.

the correlation between *Salmonella* and indicators in the stormwater runoff was not so good. The low values of r were 0.49, 0.36, 0.19 and 0.18 for total coliform, fecal coliform, fecal streptococci and enterococci, respectively. Only the correlation between total coliform and *Salmonella* was significant at the 1% level. The remaining correlation coefficients were not significant at the 5% level in the storm samples. The samples collected from the three urban streams showed no correlation between the levels of *Salmonella* and indicator microorganisms.

The relationship between the levels of *P. aeruginosa* and the levels of total coliform, fecal coliform, fecal streptococci and enterococci are shown in Figures 33a, b, c and d, respectively. The densities of *P. aeruginosa* and indicator groups were reported in comparable units. Although *P. aeruginosa* is not an enteric pathogen it is associated with and commonly found in feces. The r values for "all" and background samples are highly significant at the 1% level and were the highest observed for the data. The total and fecal coliform appeared to correlate slightly better to the levels of *P. aeruginosa* than the streptococcal indicators. For the storm samples, the significant correlation was found at the 5% level for total and fecal coliforms. No correlation was observed for fecal streptococci and enterococci. *P. aeruginosa* was found to correlate at the 99% significance level only to fecal coliforms for the stream samples.

The relationships between *Staph. aureus* and total coliform, fecal coliform, fecal streptococci and enterococci are shown in Figures 34a, b, c, and d, respectively. The levels of both pathogen and indicators are given in comparable units. Similar to the data presented for *Salmonella* and *P. aeruginosa* correlations were found at the 1% significance level for "all" and background samples. The values for the correlation coefficient were significantly higher for the latter samples. No significant correlation was observed between *Staph. aureus* and the indicator microorganisms for the storm and stream samples.

Figures 35a, b, c, and d show the correlation between the levels of enteric virus and the levels of the total coliform, fecal coliform, fecal streptococci and enterococci, respectively. The number of samples assayed for animal viruses was considerably lower than those assayed for the bacterial pathogens. The numbers of sample pairs in the analysis in each sample grouping ranged as follows: 94 to 123 for "all" samples, 46 to 57 for background samples, 54 to 66 for storm samples and 28 to 35 for stream samples. The 95% confidence intervals were calculated for correlation coefficients. In general, the correlations were poor and significant correlations at the 5% level were only found in the background sample group for total coliform and fecal coliform. Otherwise, no significant correlation between the levels of enteric viruses and indicators was observed.

INDICATOR RATIOS

The relationship between the levels of the indicator groups of microorganisms at each sample location is shown in the following series of graphs. The levels of total coliform, fecal streptococci and enterococci were compared to the levels of fecal coliforms. Theoretical

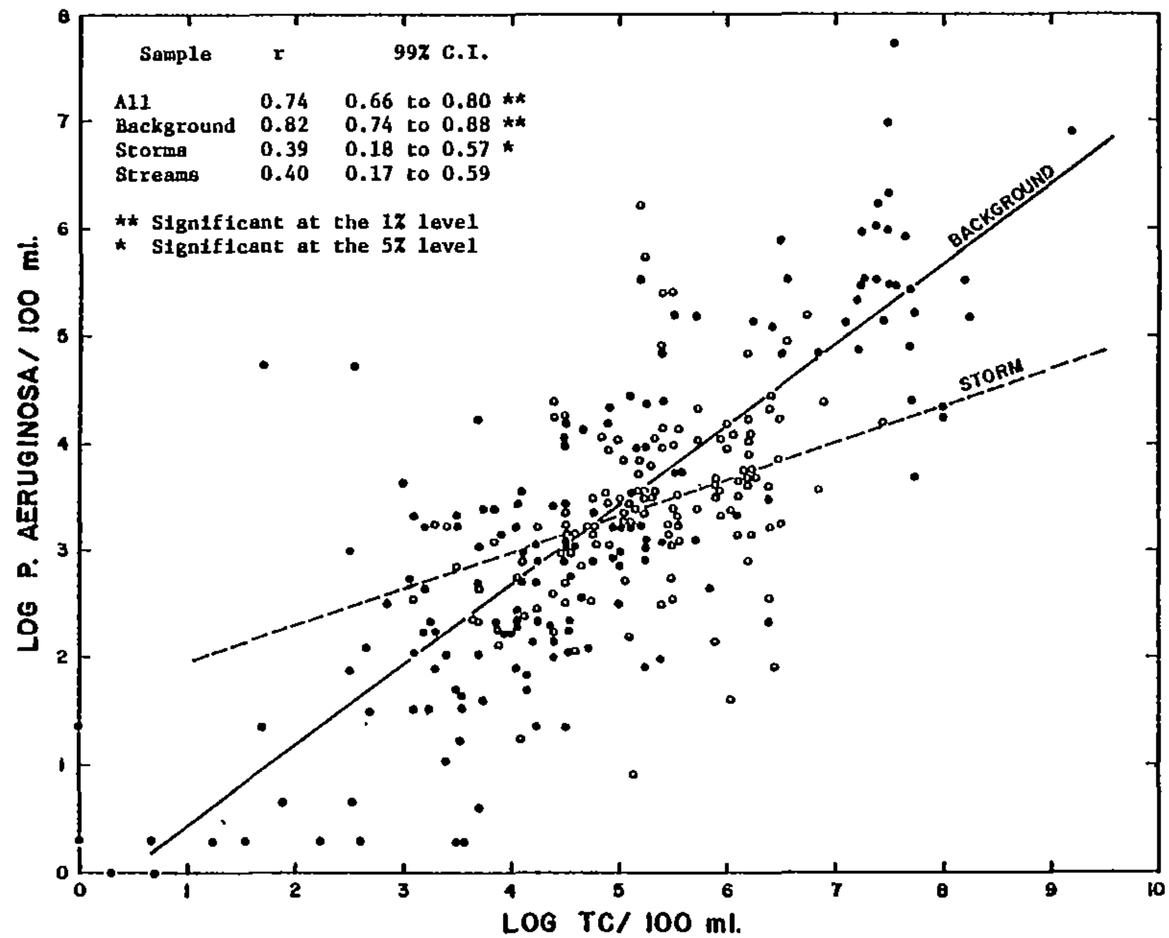


Figure 33a. Relationship between total coliform and *P. aeruginosa* in background (solid point) and stormwater (open point) samples.

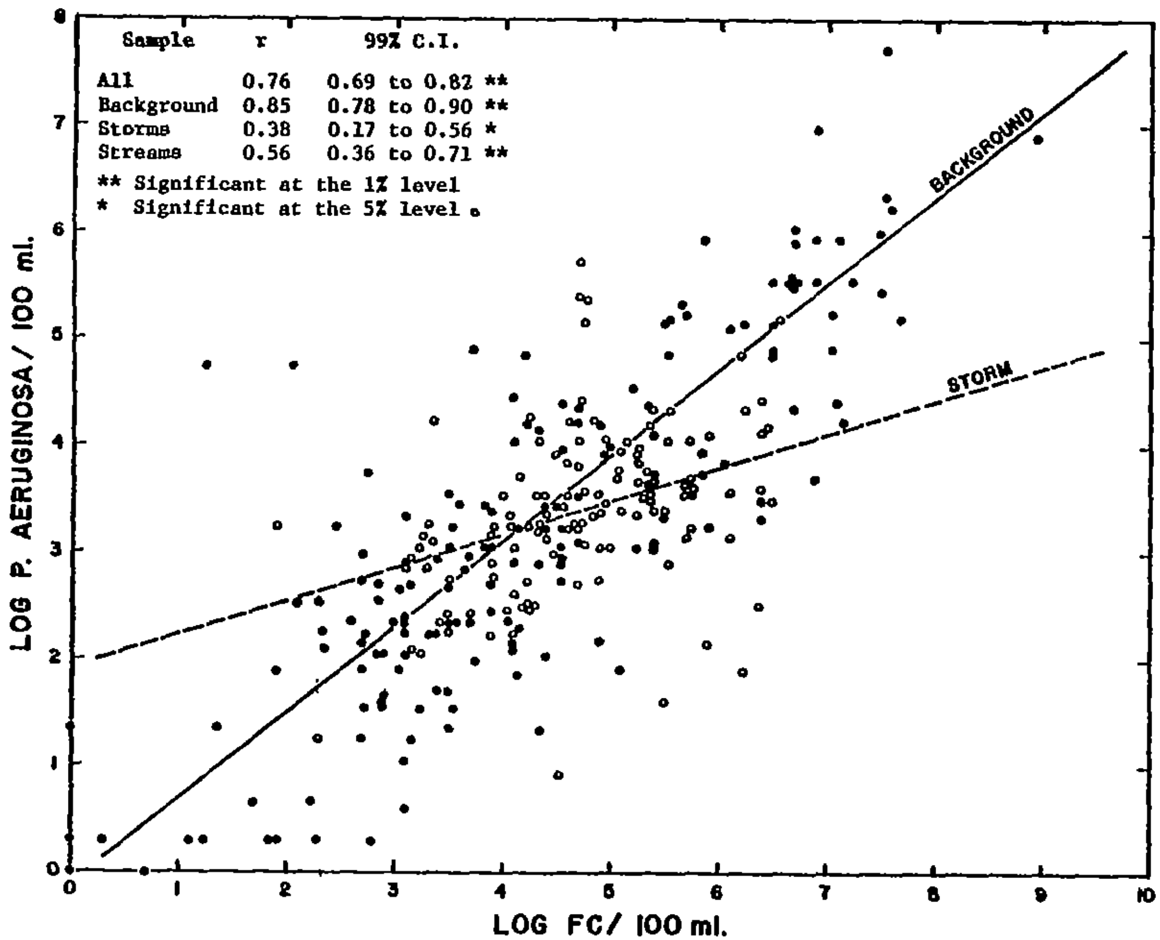


Figure 33b. Relationship between fecal coliform and *P. aeruginosa* in backgronnd (solid point) and stormwater (open point) samples.

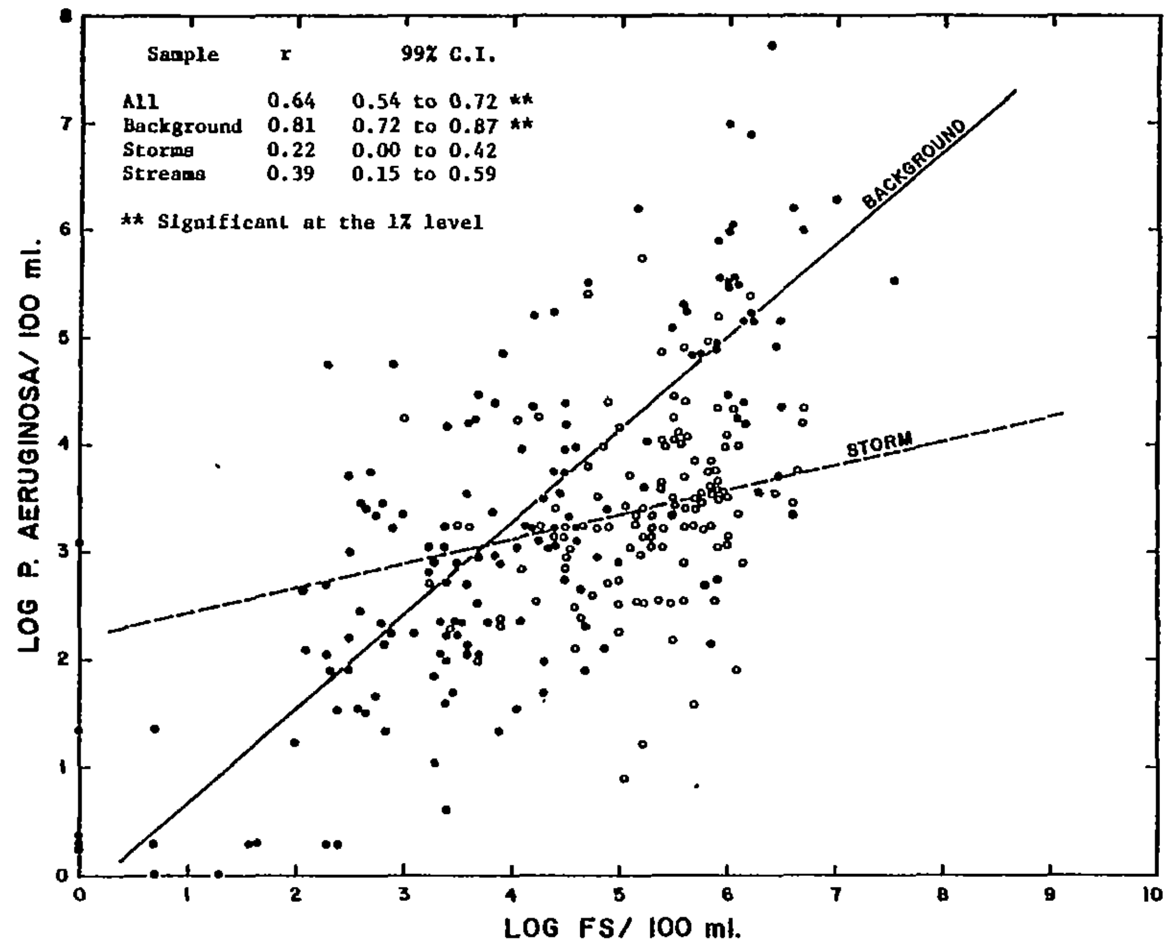


Figure 33c. Relationship between fecal streptococci and *P. aeruginosa* in background (solid point) and stormwater (open point) samples.

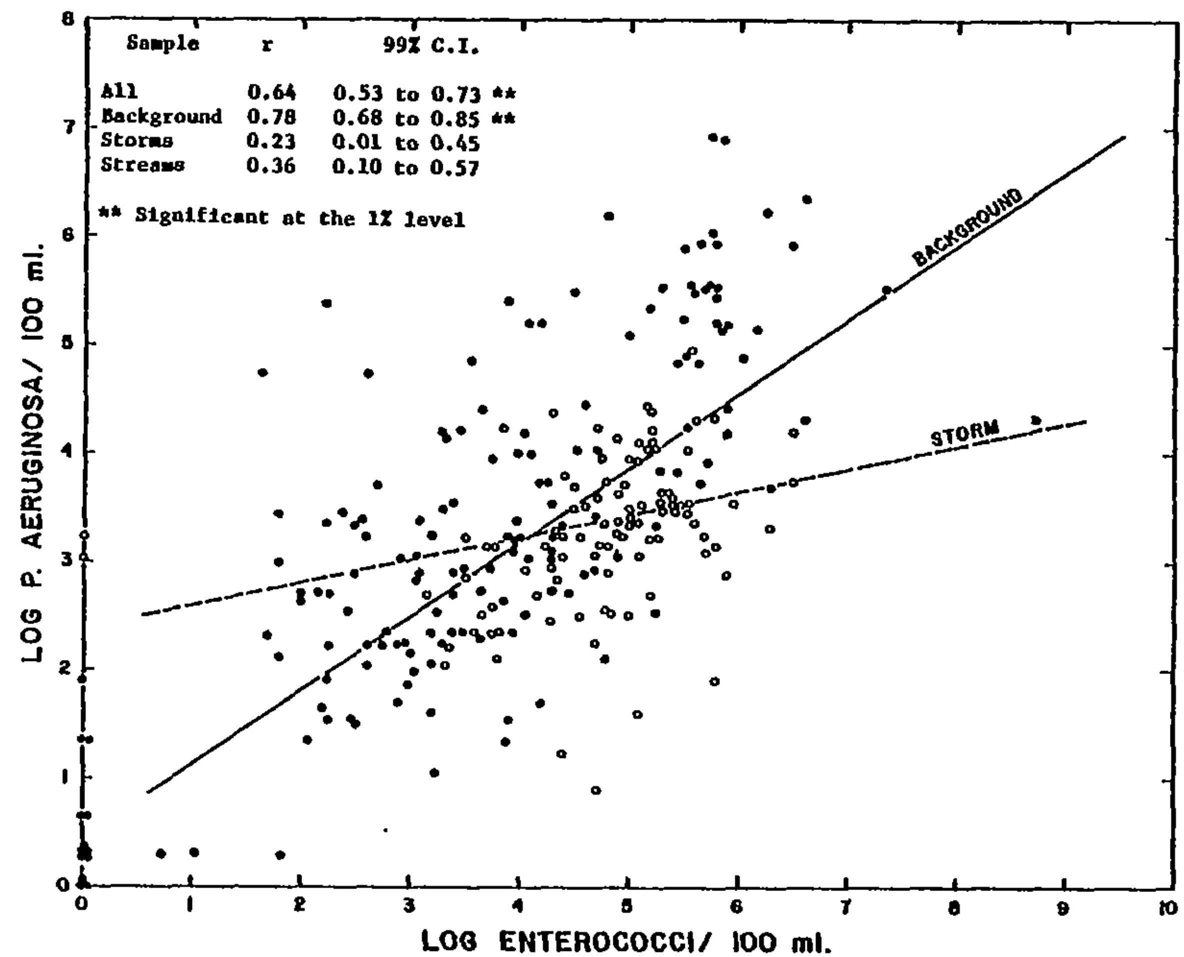


Figure 33d. Relationship between enterococci and *P. aeruginosa* in background (solid point) and stormwater (open point) samples.

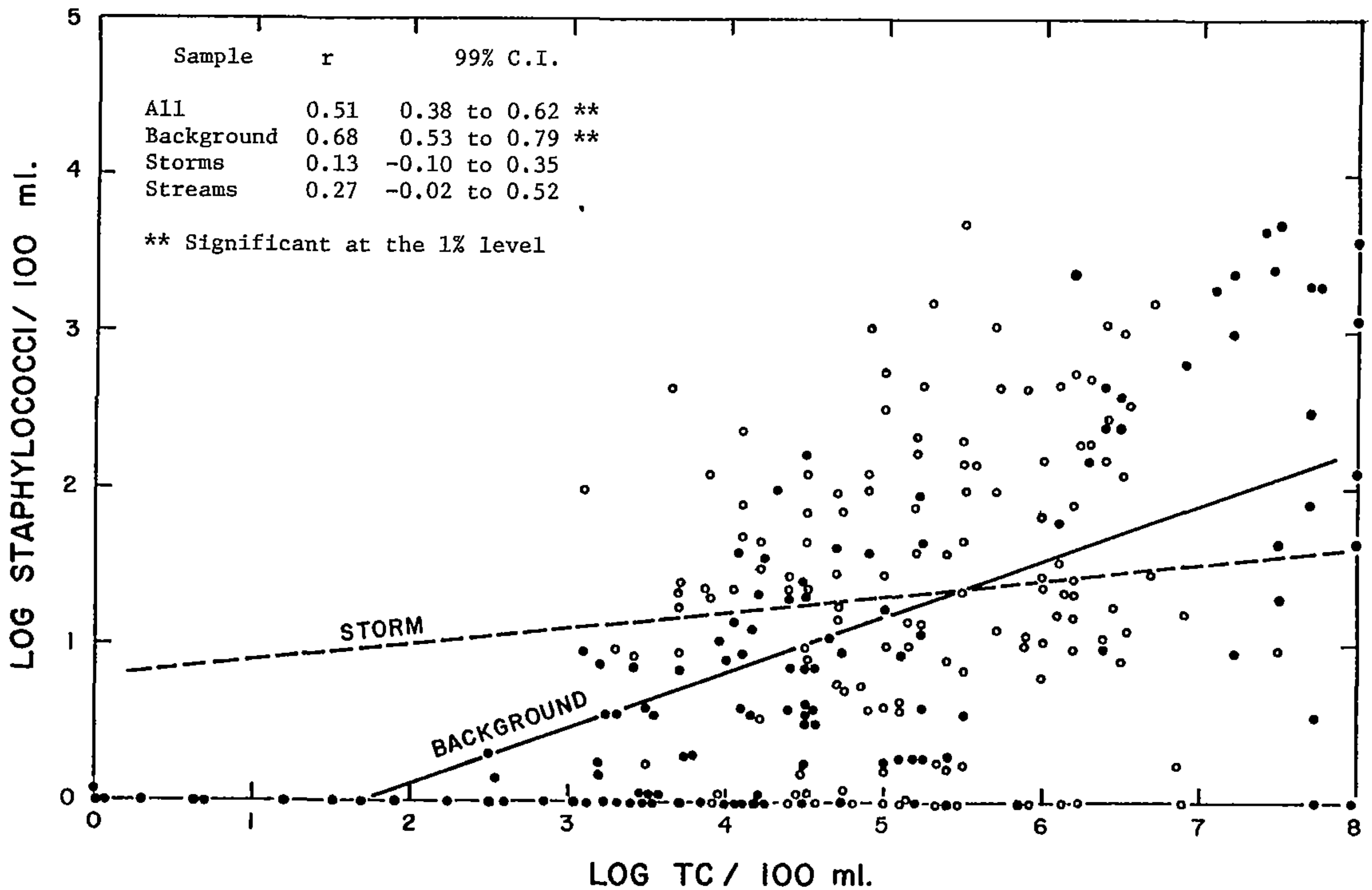


Figure 34a. Relationship between total coliform and *Staphylococcus aureus* in background (solid point) and stormwater (open point) samples.

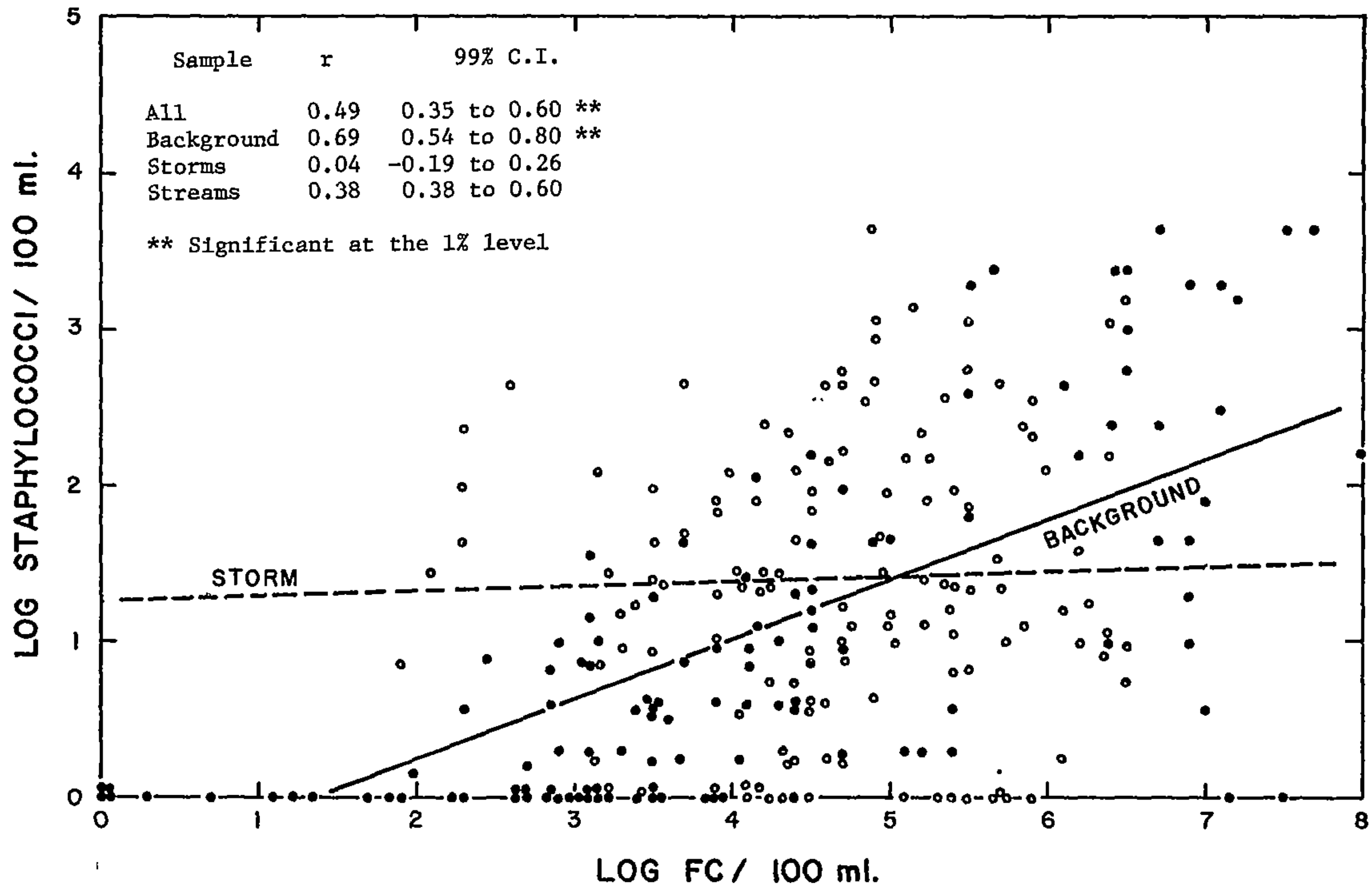


Figure 34b. Relationship between fecal coliform and *Staphylococcus aureus* in background (solid point) and stormwater (open point) samples.

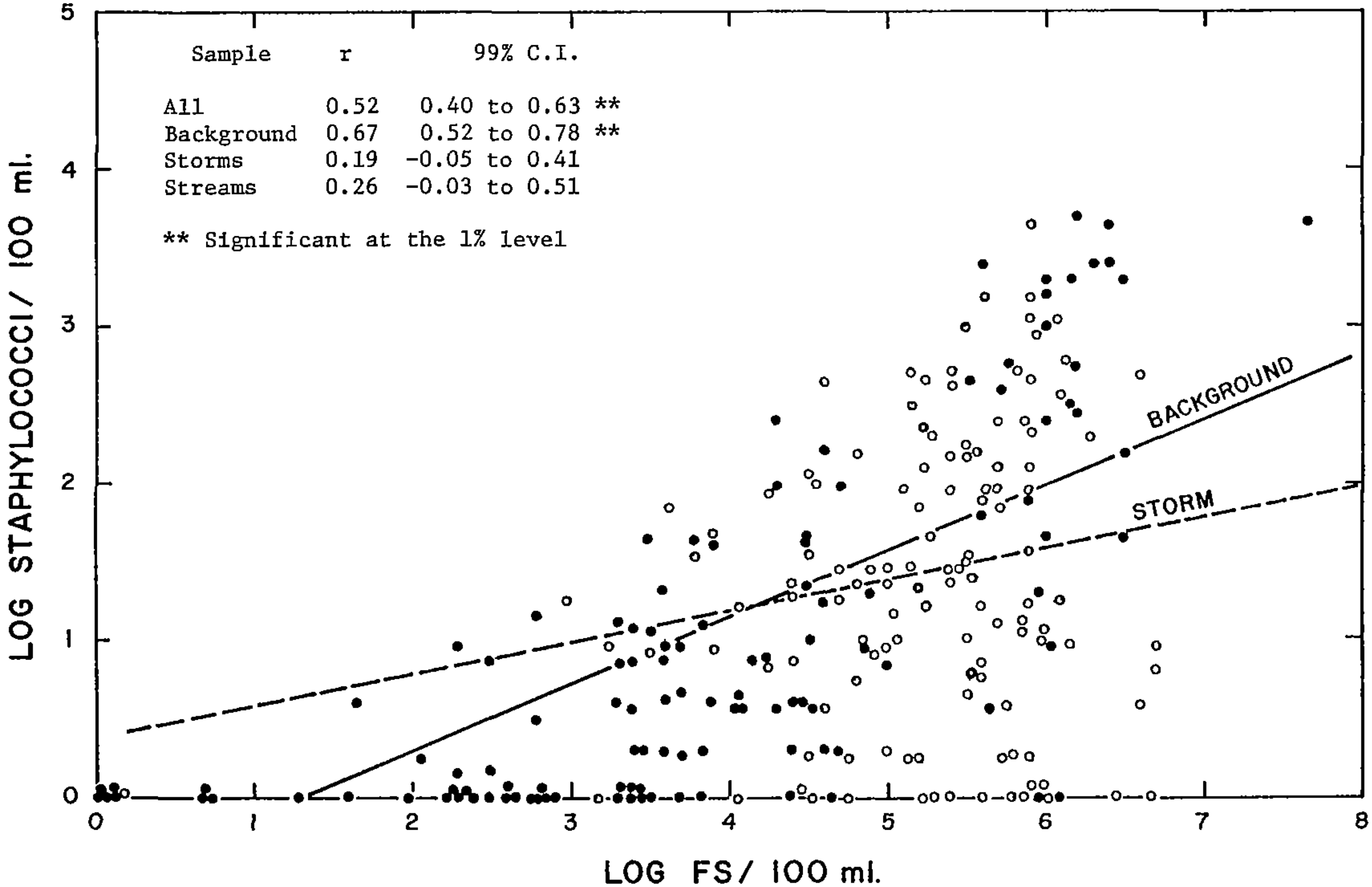


Figure 34c. Relationship between fecal streptococci and *Staphylococcus aureus* in background (solid point) and stormwater (open point) samples.

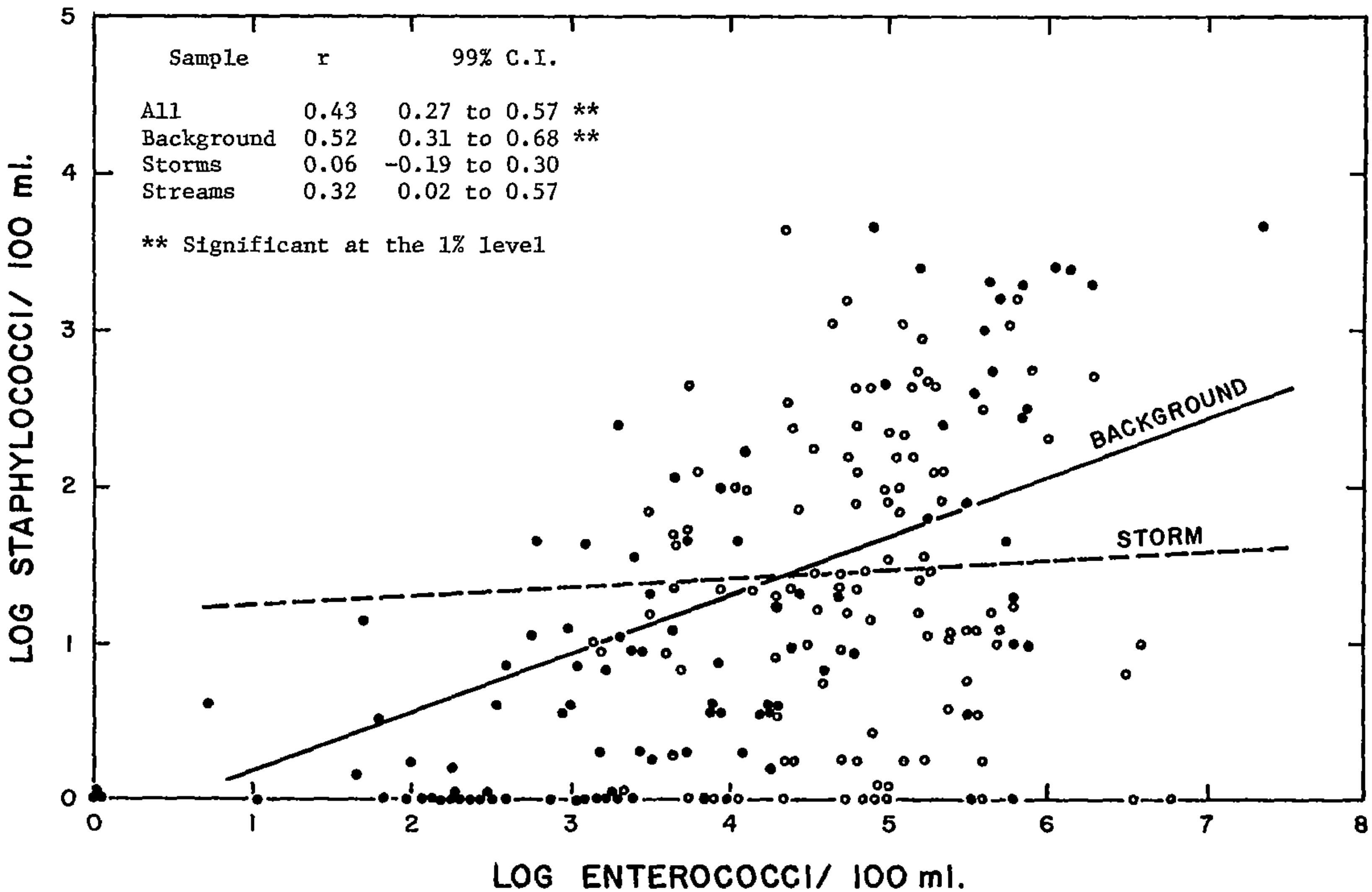


Figure 34d. Relationship between enterococci and *Staphylococcus aureus* in background (solid point) and stormwater (open point) samples.

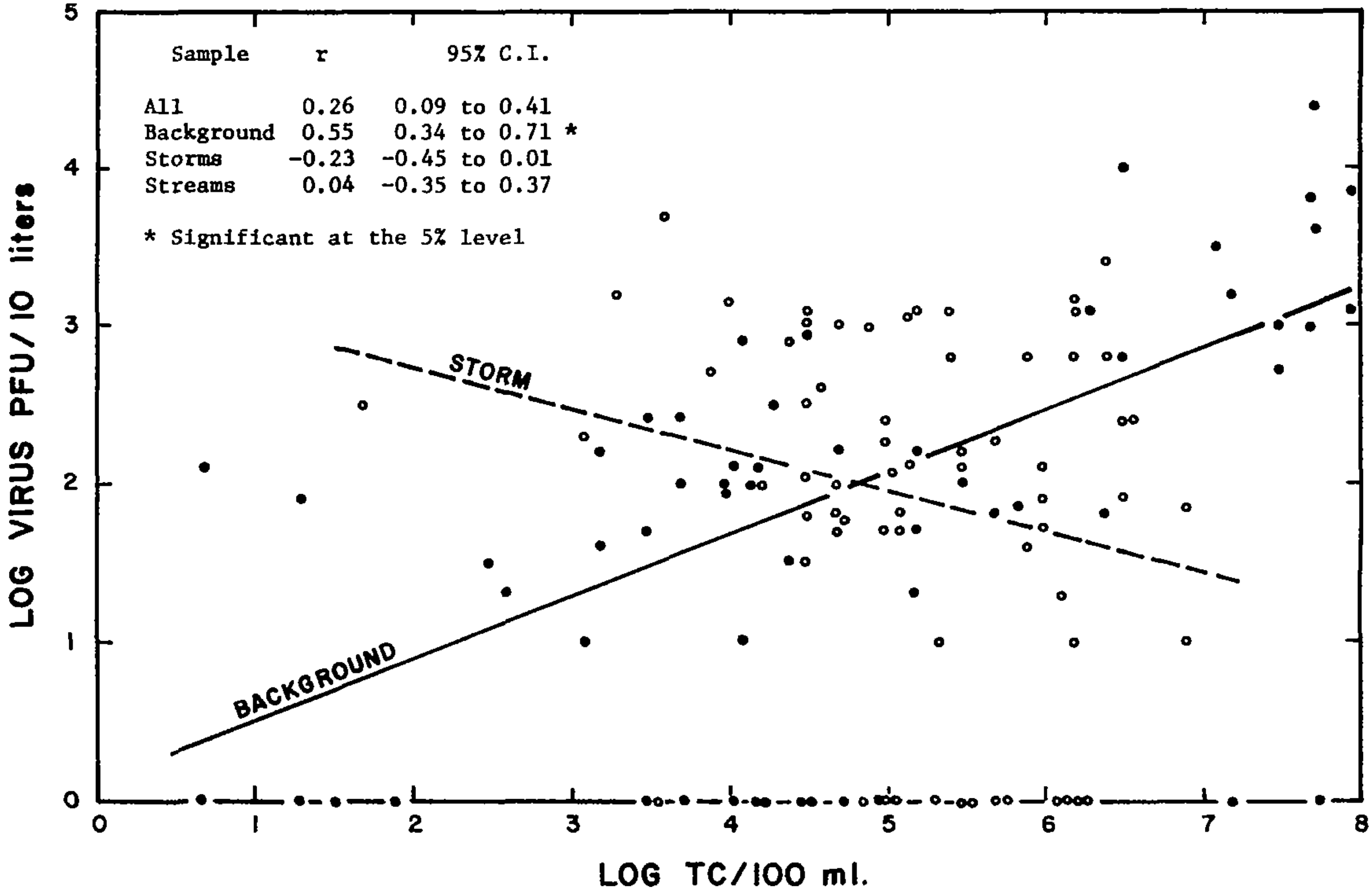


Figure 35a. Relationship between total coliform and enterovirus in background (solid point) and storm-water (open point) samples.

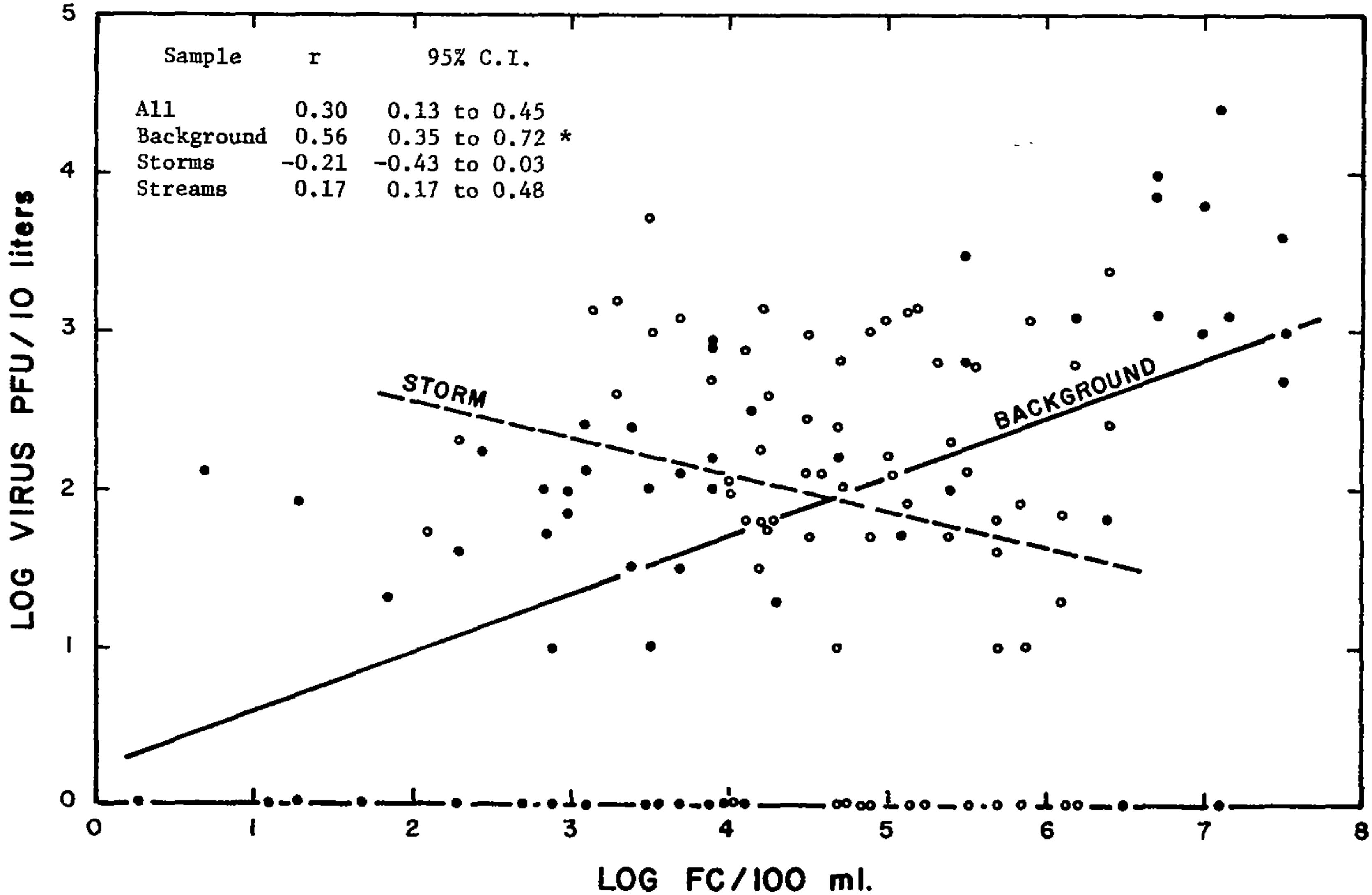


Figure 35b. Relationship between fecal coliform and enterovirus in background (solid point) and stormwater (open point) samples.

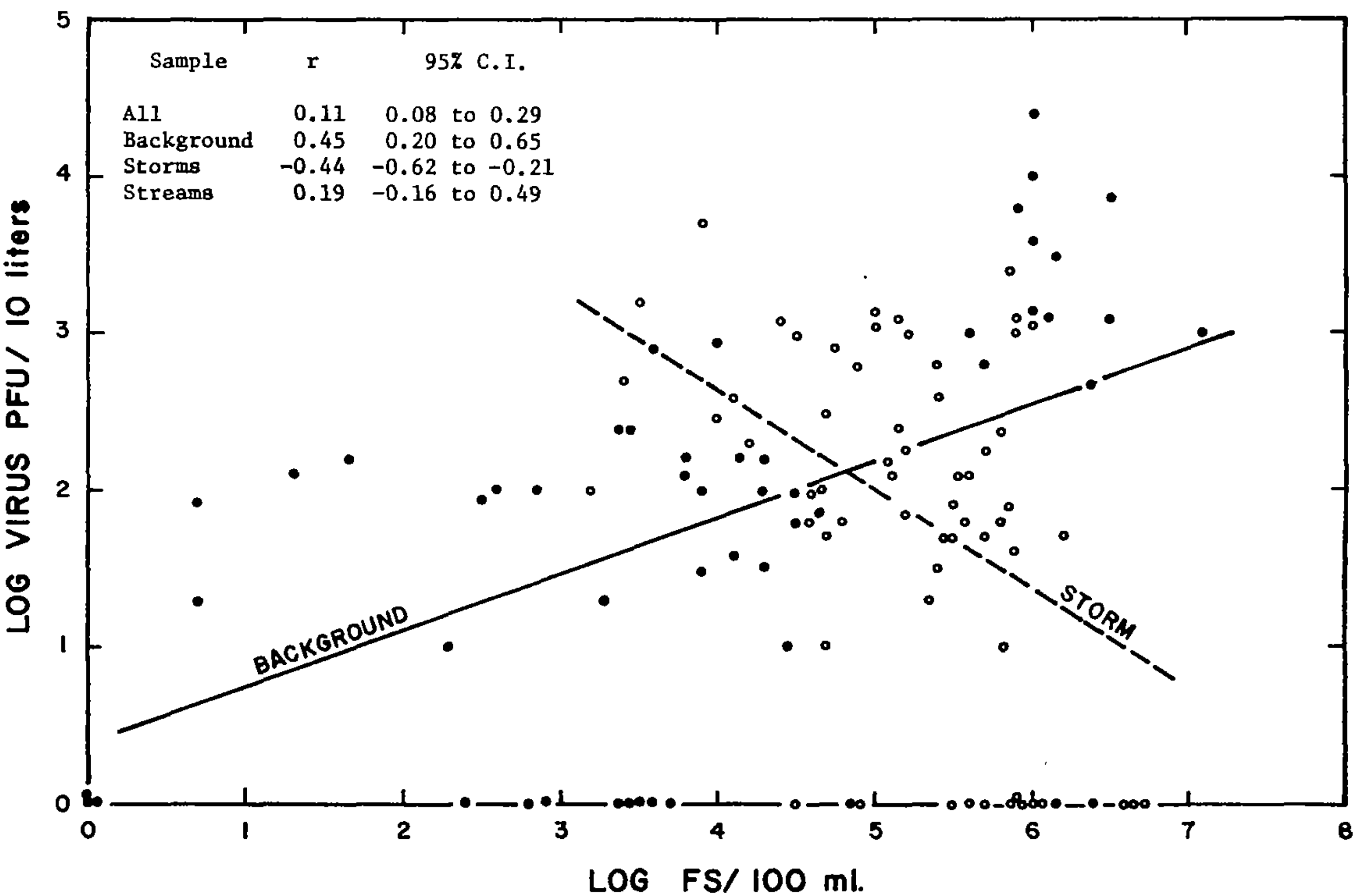


Figure 35c. **Relationship between fecal streptococci and enterovirus in background (solid point) and stormwater (open point) samples.**

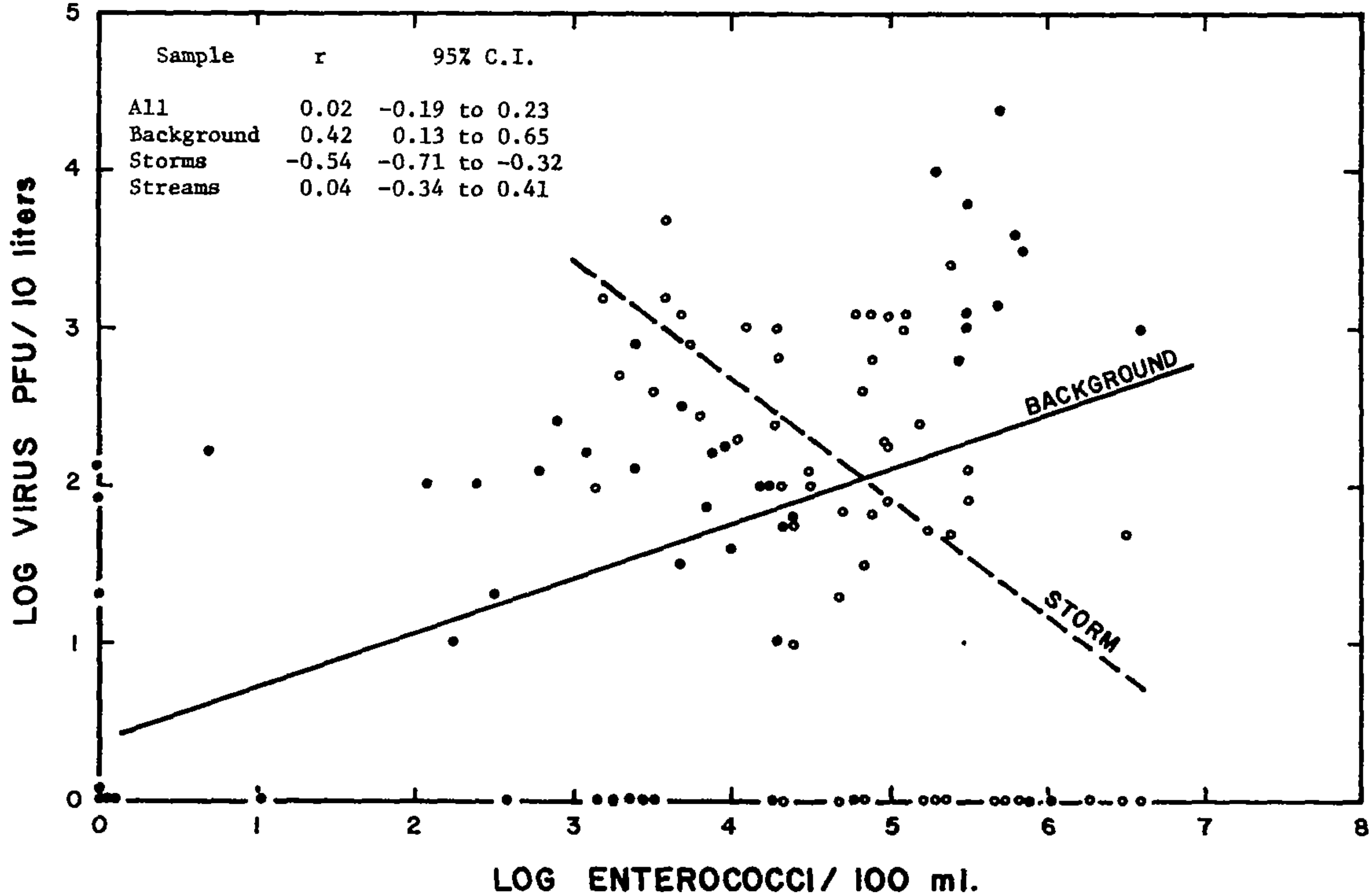


Figure 35d. Relationship between enterococci and enterovirus in background (solid point) and stormwater (open point) samples.

ratios are indicated by solid and dashed lines on each plot. The scatter of the data relative to the theoretical ratios can be seen. The ratios of total coliform to fecal coliform (FC/TC) and fecal coliform to fecal streptococci (FC/FS) are often used to evaluate the possible source of contamination. A FC/TC ratio of greater than 0.1 is believed to be indicative of sewage. A FC/FS ratio of 4.0 or greater is believed to be indicative of human feces and a ratio of 1.0 or less is believed to be indicative of animal feces.

Figure 36a shows the relative levels of total coliform, fecal streptococci and enterococci compared to the levels of fecal coliform for raw sewage taken at Back River Wastewater Treatment Plant, sample site A. The raw sewage provides a point of comparison for the data obtained for urban streams and storm runoff. FC/TC ratios in raw sewage lie between 0.01 to 1.0 with the large majority of samples having ratios of 0.1 to 1.0. The FC/FS ratios observed for raw sewage lie between 0.1 to 100 with 61% of the samples having ratios of 4.0 or greater. Similar relationships can be seen between enterococci to fecal coliform (FC/Ent). It should be noted that even in raw sewage a sizable variation between the ratios of indicators was observed.

The relationship between the levels of fecal coliforms and the other bacterial indicators in the urban streams: Herring Run, Jones Falls and Gwynns Falls is shown in Figures 36b, c and d. respectively. FC/TC ratios lie predominantly between 0.1 and 1.0 for Herring Run and Jones Falls. In the Gwynns Falls similar ratios predominate but more samples were found to have FC/TC ratios less than 0.1. Significant variability in FC/FS ratios was observed for the urban streams. About 20%, 42% and 22% of the samples had FC/FS ratios of 4.0 or greater in Herring Run, Jones Falls and Gwynns Falls, respectively. The frequency of samples with FC/FS ratios of 1 or less was 46% in Herring Run, 27% in Jones Falls and 33% in Gwynns Falls. A large portion of the samples in each of the urban streams had FC/FS ratios in the intermediate range of between 1.0 and 4.0. Similar results were obtained with enterococci levels when compared to fecal coliform data.

The relationships between the indicator groups of microorganisms for the storm samples are shown by site in Figure 37a through 37f. FC/TC ratios in the large majority of the samples collected at each of the storm locations lie between 0.1 to 1.0. FC/FS ratios found in the storm samples are markedly different from those observed for the background samples. More than 90% of the samples collected at Stoney Run (Figure 37a), Glen Avenue (Figure 37b), Bush Street (Figure 37e) and Northwood Figure 37f) had FC/FS ratios less than 4.0. Greater than 80% of the samples from these stations had FC/FS ratios of 1.0 or less. Only 18% and 12% of the samples collected at Howard Park (Figure 37c) and the Jones Falls storm drain (Figure 37d) had FC/FS ratios of 4.0 or greater. The frequency of samples of these stations with FC/FS ratios of 1.0 or less was 41% for Howard Park and 76% for the Jones Falls storm drain. Ratios of FC/Ent. appeared to shift up slightly for the storm runoff samples compared to the FC/FS. In each case a larger percentage of samples had FC/Ent. ratios greater than 1.0. Unfortunately, the significance of FC/Ent. ratios have not been evaluated.

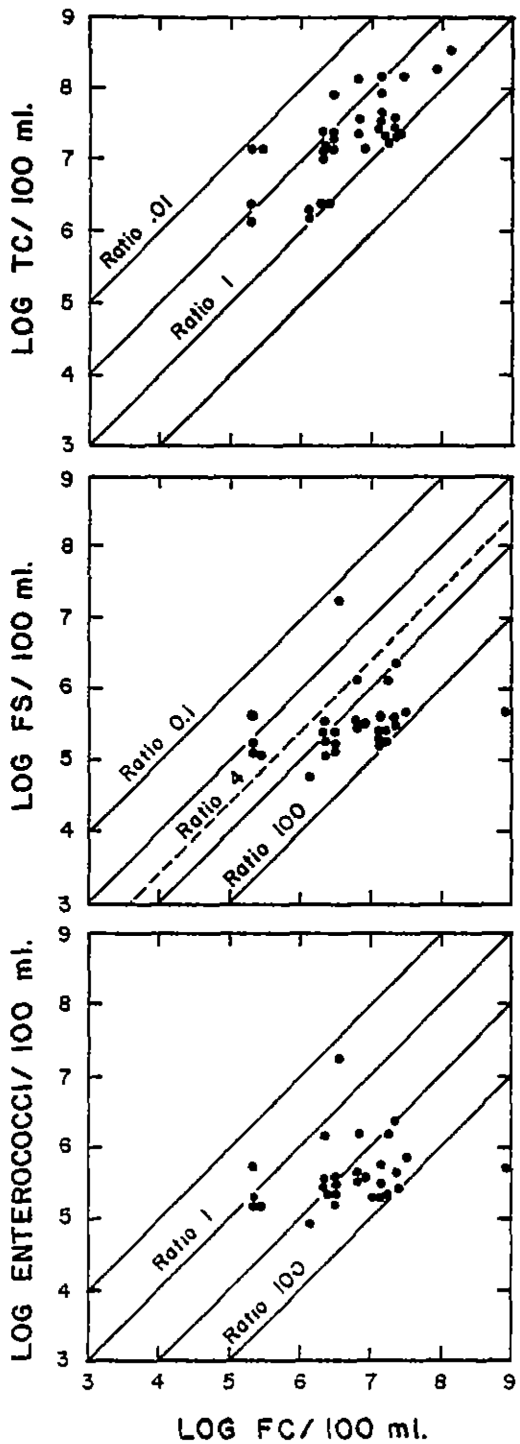


Figure 36a. Back River raw sewage, site A. Ratio of fecal coliform to total coliform, fecal streptococci, and enterococci.